FINAL REPORT

Endangered Species Project SE-1-10

Sturgeon Studies in Missouri, Job No. 1

Abundance and Life History of the Lake, Pallid, and Shovelnose Sturgeons in Missouri

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INTRODUCTION

Three species of the sturgeon family Acipenseridae occur in the Mississippi Valley: lake sturgeon (*Acipenser fulvescens*), pallid sturgeon (*Scaphirhynchus albus*), and shovelnose sturgeon (*Scaphirhynchus platorynchus*). All have been depleted throughout much of their original range because of over-fishing, pollution, the construction of dams, and the alteration of river channels for navigation.

In Missouri the lake sturgeon and pallid sturgeon are listed as endangered (Nordstrom et al. 1977), and are protected under Rule 3CSR10-4.111 of the Wildlife Code of Missouri. The shovelnose sturgeon, though depleted, is still sufficiently common to support a limited commercial fishery. All three species occur mainly in the Missouri and Mississippi rivers (Pflieger 1971). The objectives of this study were to better define the distribution and abundance of the lake sturgeon and pallid sturgeon in Missouri; to identify existing and potential threats to their survival; and to develop recommendations for enhancing their status. Comparative information was obtained on the shovelnose sturgeon because of its close relationship to the pallid sturgeon, and because of the opportunity for study afforded by the planned investigations of its more seriously threatened relatives.

TAXONOMIC RELATIONSHIPS AND IDENTIFICATION

Of the 20 or more species and subspecies of sturgeons that occur in the Northern Hemisphere, all belong to the family Acipenseridae and most to the genus *Acipenser* (Dees 1961). The lake sturgeon is a member of this genus. The genus *Scaphirhynchus* comprises two currently recognized species, the pallid sturgeon and the shovelnose sturgeon. A third undescribed and nearly extinct form occurs in the Alabama River system (Lee 1980).

The sturgeons are easily recognized by their superficially shark-like appearance, lengthwise rows of bony plates along the body and prominent barbels beneath the well developed snout. Characteristics for identifying the three species of sturgeons that occur in Missouri were listed and illustrated in an identification leaflet prepared for use by commercial fishermen and others (Appendix 1).

STUDY AREA

This study was conducted in the Missouri and Mississippi rivers, in and adjoining the state of Missouri. Based on differences in volume of flow, substrate, and other factors, we divided the study streams into five sections as follows: (1) "Middle Missouri River", Iowa border to Kansas City; (2) "Lower Missouri River", Kansas City to mouth; (3) "Upper Mississippi River", Iowa border to mouth of Missouri River; (4) "Middle Mississippi River", mouth of Missouri River to mouth of Ohio River; and (5) "Lower Mississippi River", mouth of Ohio River to Arkansas border (Fig. 1).

A general description of the Missouri and Mississippi rivers as habitat for fishes was presented by Pflieger 1971. More detailed information on the physical, chemical, and biological aspects of these rivers and the changes they have undergone as a result of man's activities was presented by Berner 1951, Funk and Robinson 1974, Hallberg et al. 1979, Nord 1967, Simons et al. 1975, Rasmussen 1979, and Whitley and Campbell 1974.

Missouri River

Historically, the Missouri River was one of the most turbid large streams on the North American Continent, and occupied a wide, braided

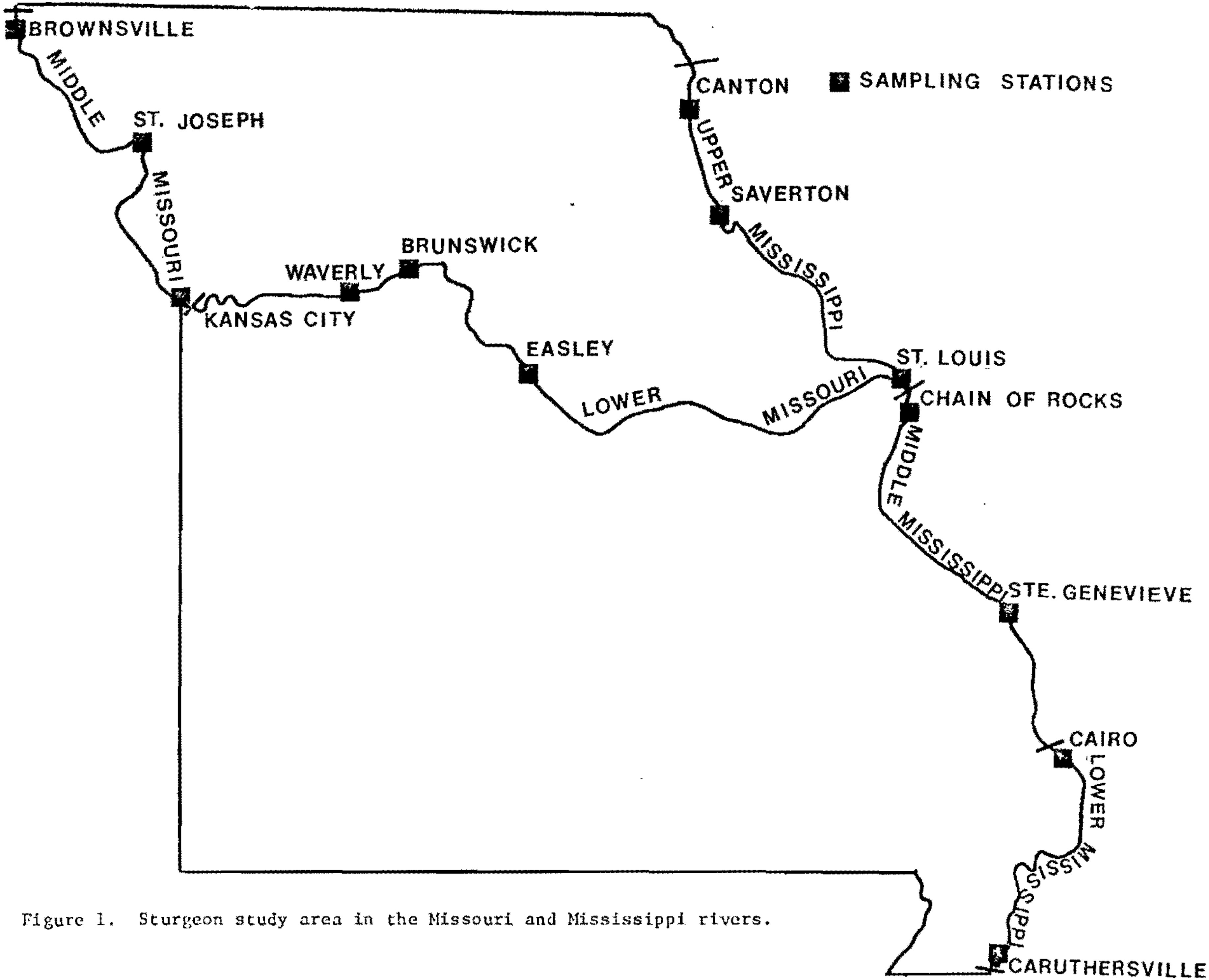

Figure 1. Sturgeon study area in the Missouri and Mississippi rivers.

channel that was in a constant state of change. This instability resulted from the rapid current, substantial bedload of fine sediments, and wide fluctuations in volume of flow. Efforts by the U. S. Army Corps of Engineers to stabilize and deepen the channel for navigation have profoundly altered the environment of the Missouri River. These efforts began before 1900, but were considerably intensified in recent decades. At present the Missouri River in Missouri is confined to a single narrow channel of rather uniform width, with swift current, and few quiet backwaters (Funk and Robinson 1974). The habitat diversity formerly associated with numerous side channels, islands, and sand bars has been substantially reduced. These changes resulted from the construction of rock dikes and revetments. Efforts are now being made to restore some of the lost diversity through changes in the design of these structures, but the benefits of the changes in terms of improved fish populations are undocumented (Burke and Robinson 1979). The construction of six large main stream reservoirs on the upper river have modified the natural flow regimen and measurably reduced the turbidity, further affecting the downstream environment.

The Middle Missouri Section has been more intensively channelized than the Lower Missouri Section, has considerably less flow, and is less subject to rapid changes in river stage due to the influence of upstream reservoirs. The Lower Missouri Section receives flow from several substantial tributaries, including the Kansas, Grand, Osage, and Gasconade rivers. As a result, the flow of the Missouri River nearly doubles as it passes through the state. The boundary between these two river sections is the mouth of the Kansas River at Kansas City (Fig. 1).

Mississippi River

Because of differences in the physiography and climate of the regions through which they flow, the Mississippi River and Missouri River are very different. The flow of the Upper Mississippi is 18% greater than that of the Missouri River, even though its drainage area is only 32% that of the Missouri. This is because the Mississippi drainage receives more precipitation. The Upper Mississippi River (above the mouth of the Missouri River) once consisted of a series of deep pools separated by shallow bars and rapids (Carlander 1954). It was clearer than the Missouri, and the substrate consisted of a greater proportion of rocks and gravel. The Upper Mississippi River has been converted into a series of river lakes through the construction of navigation locks and dams. Six of these dams are in Missouri. Areas of river-like habitat are still present near the upper ends of the navigation pools (Rasmussen 1979), but most of the remaining habitat is lucustrine, with clear water and a silty bottom. Habitat diversity is greater than in the Missouri River; side channels and sloughs are numerous.

The Middle Mississippi River (mouth of Missouri River to mouth of Ohio River) has much the same character as the lower Missouri River, but on a larger scale (Pflieger 1971). Channelization has been accomplished here as in the Missouri River by the construction of wing dikes and revetments. The Chain of Rocks area just above St. Louis is unlike the remainder of the Middle Mississippi. There, a navigation canal circumvents a natural rapids, and a low dam over these rapids is a partial barrier to upstream movement of fishes. The Mississippi River enters the broad alluvial plain of the lower Mississippi Valley near Cape Girardeau, but there is little immediate effect

on the habitat of the river channel.

The flow in the Lower Mississippi River is more than double that in the Middle Mississippi because of the contribution by the Ohio River. Water clarity in the Lower Mississippi is also noticeably increased, and the channel is wider and deeper, with a greater proportion of standing-water habitats. The substrate is primarily sand and gravel.

METHODS

Sturgeon data came from three sources: interviews with commercial fishermen, records of commercial harvest, and field collections. The interviews were helpful in selecting sampling areas and gear. A postcard survey was used to interview 578 commercial fishermen in spring, 1978. Missouri fishermen who licensed at least six trot lines, four hoop nets, or two entanglement nets were contacted, along with all of the 229 out-of-state fishermen that fish adjoining waters. Questionnaire packets included a letter of introduction (Appendix 2), a sturgeon identification sheet (Appendix 1), and a returnable postcard requesting information on the kinds and locations of the sturgeons they catch (Appendix 3). Follow-up phone calls were made in spring, 1979 to 13 fishermen who offered additional information.

Field sampling was conducted in spring and fall 1978 and spring 1979 in 13 areas (Fig. 1). Three areas (Brownsville, St. Joseph, and Kansas City) were in the Middle Missouri River, four (Waverly, Brunswick, Easley, and St. Louis) were in the Lower Missouri River, two (Canton and Saverton) were in the Upper Mississippi River, two (Chain of Rocks and Ste. Genevieve) were in the Middle Mississippi River, and two (Cairo and Caruthersville)

were in the Lower Mississippi River. From 3.2 to 24.1 km of river were sampled at each site, in habitats that previous experience indicated would be frequented by sturgeons. Water temperature and depth, and the locations where pallid sturgeon were caught were recorded for each area. Bottom contours were charted with a fathometer and the bottom velocity was measured with a flow meter and stop watch.

Fish were collected with eight types of gear, but trot lines and trammel nets were used most often. Trot lines consisted of 10 hooks (1/0 Eagle claw) spaced at 1 m intervals on 25 cm drops. Hooks were baited with worms (night crawlers and "river worms"). Lines were set behind rock dikes and on the inside of river bends where sand bars were 0.6-3.1 m beneath the surface, and currents were moderate. The lines were raised twice daily to remove fish and add new bait. Nylon trammel nets (6.4 cm square mesh inner walling, 30.5 cm square outer walling, 2.4 m deep, 46 m long) were weighted and set to fish near the bottom behind wing dikes in deep (6.1-12.2 m), quiet water. Trammel nets with weights omitted and floats adjusted so the nets would hang vertically were drifted along the bottom in areas of greatest sturgeon concentrations, usually in fast to moderate current.

Many sturgeons were dipped in a sort of weir on the Mississippi River just below Chain of Rocks Dam at St. Louis. This weir consisted of the grates and screens of a city water intake that unintentionally entrapped migrating sturgeon when they attempted to go around the impassible part of the dam. Sturgeon were drawn into a 15.3 m deep forebay and were easily collected with a dip net. At other sites, we used electrofishing gear (pulsed, direct current at 120 pulses/sec and 50% duty cycle at 8 amps),

a 4.9 m semi-balloon trawl (with 3.8 cm mesh), and hoop nets and gill nets (5.1 cm square mesh).

Catch per unit of effort was standardized among gear types by taking the gear units (i.e. number of hook half-days) that could be processed in an average day and calling it a "gear-day". The gear-day equivalents were 200 hook half-days, 5 dip net collections at the weir, 10 trammel net drifts, 6 dead set trammel net half-days, 6 hoop net half-days and 10 trawl hauls. The common and scientific names used in this report conform to Bailey et al. 1970.

The species and fork length (F.L.) of each sturgeon was recorded. Most shovelnose sturgeon were tagged and released, but a representative group of 5-15 individuals was dissected for internal examination. From these fish, the gonads were examined to determine sex and reproductive condition, the stomachs were preserved for food habit studies, and the first pectoral fin ray was kept for aging. Otoliths were kept from a few fish to compare aging techniques, and tissue samples from selected individuals were frozen in dry ice for electrophoretic analysis. A representative series of specimens was preserved entire in 10% formaldehyde. Pallid sturgeon were either tagged and released, or processed as above.

In the laboratory, stomachs were transferred from the field preservative (10% formalin) to 70% ethanol, and then cut open to remove and volumetrically measure the contents. Food items were sorted and identified to the lowest possible taxonomic level, and the percent of each was estimated visually.

Sturgeon were aged by microscopic examination of sections of pectoral fin rays (Cuerrier 1951) and otoliths. Annuli were counted toward the anterior apex of the fin-ray section to minimize errors in counts (Sokolov

and Akimova 1976). Otoliths were imbedded in epoxy resin, sectioned with a jewelers saw, polished on an abrasive block, and examined under a compound microscope.

Stage of gonadal development was determined in the field. Six stages were recognized for females: Stage 1 - Ovaries consisting of over 90% fat and minute eggs; Stage 2 - tiny translucent eggs aligned in laminated groups; Stage 3 - small white, partially pigmented eggs occupying over half the gonad; Stage 4 - full-sized gray eggs; Stage 5 - full-sized black eggs; and Stage 6 - eggs resorbing or recently spent. These stages approximate stages 1, 2, 3, 4-5, 6, for females as reported by Moos (1978). Three stages were recognized for males: Stage 1 - testes undeveloped; Stage 2 - testes full-size but not secreting milt when cut; and Stage 3 - testes secreting milt when cut. These stages approximate stages 1, 2-4 and 5 for males as reported by Moos (1978).

To document apparent hybridization between the two species of Scaphirhynchus, electrophoretic analysis of tissues from 10 pallid sturgeon, 74 shovelnose sturgeon, and 6 presumed hybrids were made as described by Allendorf et al. 1977 and May et al. 1979 . Tissue samples (eye, heart, liver, muscle, brain, and intestine) were analyzed within 5 months after they were collected.

Further documentation of hybridization was obtained by analysis of proportional body measurements, fin ray counts, and other external features. Standard length, head length, rostral length, orbit length, mouth width, length of inner barbel, length of outer barbel, distance between inner barbel and mouth, distance between outer barbel and snout tip, and height of 10th lateral plate were measured. Measurements were standardized by converting

them to thousandths of standard length. Rays of the dorsal, anal, pectoral and pelvic fins were counted. Measurements and counts were made as described by Bailey and Cross 1954.

We devised an analytical technique (Character Index) that could be applied without advance knowledge of the identity of any specimen. This Character Index is basically the Hybrid Index of Hubbs and Kuronuma 1942, except in their index the average value of each character of the parental types provided the basis for comparison, and they expressed their index on a scale of 0 to 100. We did not use their index in our preliminary analysis because we could not confidently identify the parental types. Our index, which ranges between 0 and 1,000, was computed as follows: Using the findings of Bailey and Cross 1954 as a guide, we determined for each of the 13 characters studied, the most platorynchus-like value for any of the 30 specimens we used in our comparisons, and set this value at 0. In a similar way, the most albus-like value was set at 1,000. The values obtained for the other 28 specimens were then expressed on this scale of 0 to 1,000. These standardized values for the 13 characters of each specimen were then summed and averaged, giving the Character Index.

This index provides a single expression of how each specimen used in the analysis compares with every other specimen in the composite of the characters studied. It can be used to objectively rank the specimens, with the most platorynchus-like specimen at one extreme of the ranking and the most albus-like specimen at the other extreme.

The movement of shovelnose sturgeon was determined by the recapture of tagged fish. Numbered tags with the letters "Mo. Dept. Cons." were attached to 3,113 shovelnose sturgeon. Plastic cinch-up tags (Floy tag

size 4) were inserted through the front and back of the dorsal fin on all fish large enough to carry the 23 mm plastic sheath. Self-piercing monel strap tags (National tag size 3 or 4) were attached to the base of the pectoral fin on smaller fish (Helms 1974a).

Statistical tests performed on the data used the α = .05 level of probability unless otherwise stated.

RESULTS AND DISCUSSION

The fisherman interviews, the literature search, and the field collections provided many new insights about sturgeons, and demonstrated the need for evaluating every possible data source. For example, commercial harvest records might be examined to determine changes in abundance, and a decline in harvest might be interpreted as a trend in abundance. However, the influences of average fish size or change in marketability of that species might have been more significant than changes in the abundance.

In this section we present and discuss all sources of data for each species separately. The commercial fishermen interviews relate to all three species and are presented first.

FISHERMEN SURVEY

Commercial fishermen caught sturgeons in all study sections of the Mississippi and Missouri rivers, but the survey responses by 171 fishermen showed differences in the species caught in different sections of the study streams. Pallid sturgeon were reported by only 6% of the fishermen. Lake sturgeon were reported by only 8% of the fishermen, and 8 of the 13 specimens reported came from the Upper Mississippi River. Shovelnose sturgeon were reported by 74% of the fishermen. Even though this species was caught in all reaches of the study streams, it was caught most frequently in the Middle Missouri Section.

According to fishermen reports, the value, or marketability of shovelnose sturgeon was low except in the Upper Mississippi River. In other study sections, only 21% of the fishermen valued the shovelnose sturgeon, but in the Upper Mississippi River, 73% of the fishermen attributed a high value to this species.

LAKE STURGEON

No lake sturgeon were caught during this study, but the following review is provided because of the former importance of this species and the potential of its restoration in Missouri.

Distribution and Abundance

The lake sturgeon ranged widely in the Mississippi Valley prior to 1900, but it has declined markedly since that time. It formerly occurred in most major streams of the Mississippi drainage, and in Missouri it was reported from the Missouri, Mississippi, and Osage rivers (Pflieger 1975). Today, the largest United States populations are in the Upper Mississippi Drainage. Self-sustaining populations occur in the St. Croix River of Minnesota and Wisconsin, and the Flambeau and Wisconsin rivers of Wisconsin (Priegel and Wirth 1971). Scattered sightings are reported southward in the Mississippi River and its tributaries. We know of only two lake sturgeon caught by Missouri fishermen in 1978-79, and we caught none during 104 gear-days of sampling. These two reports were from the Upper Mississippi River (Fig. 2).

The historic trends in abundance of lake sturgeon in the Mississippi River system are shown by commercial harvest statistics, which are available for 1894, 1899, and 1922. Such statistics are only estimates, and perhaps

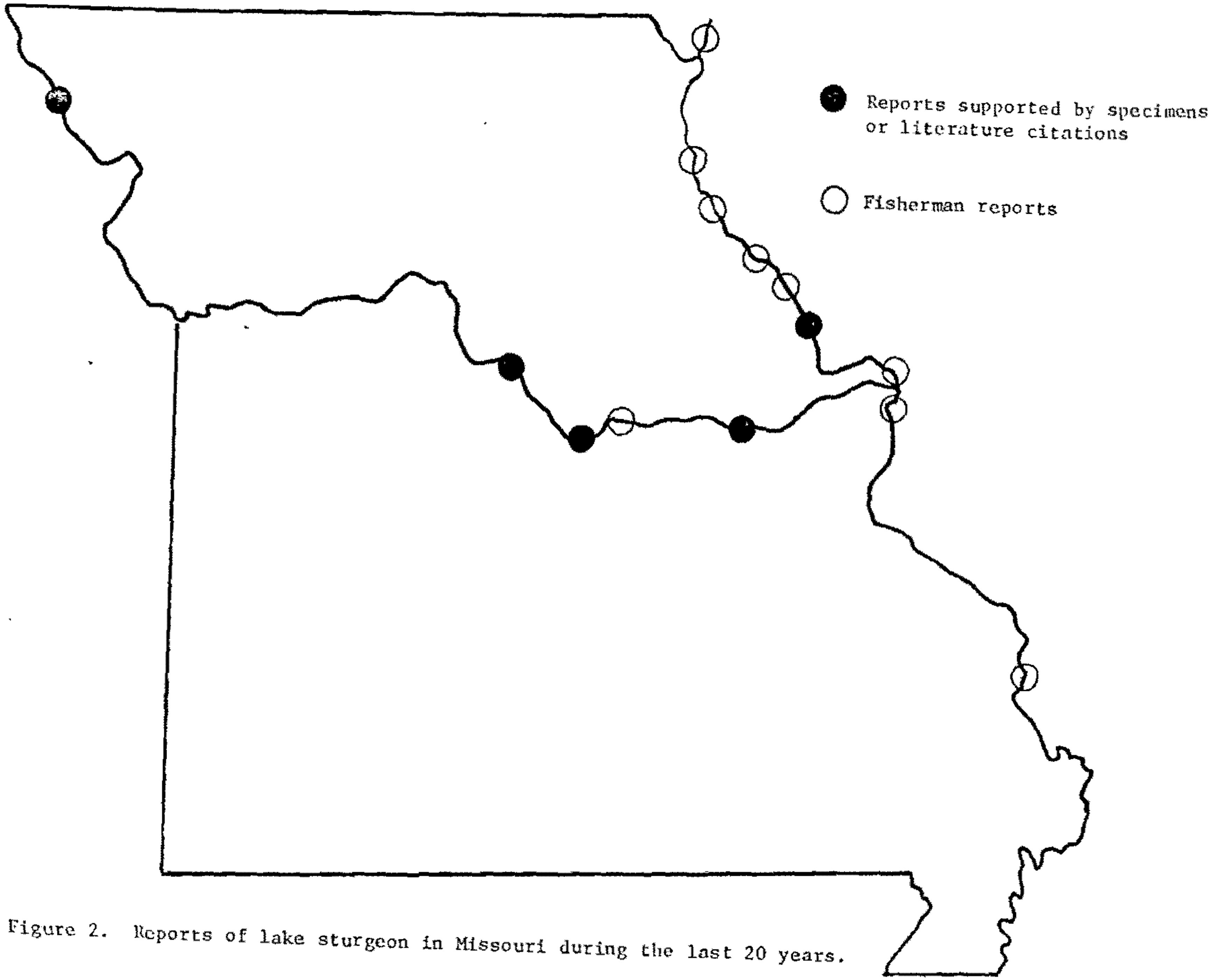

Figure 2. Reports of lake sturgeon in Missouri during the last 20 years.

are minimum values. The lake sturgeon harvest for the Mississippi Valley was 135 T in 1894, 106 T in 1899, and 5 T in 1922 - a decline of 96% over this period (Smith 1898, Townsend 1902, Sette 1925). Lake sturgeon harvest records were discontinued after 1922 because of the fish's scarcity.

The largest harvest (42-57%) came from the northern Mississippi River in Minnesota and Wisconsin, with the Ohio and Missouri rivers providing the next largest harvests. Missouri accounted for 4-39% of the harvest, averaging 10% for the two years of largest harvest. In early years 78% of the Missouri harvest came from the Mississippi River, but in 1922 the Mississippi River harvest was only 0.3 T, about half that of the Osage River.

Overfishing was probably the principal cause for the decline, just as in the Great Lakes (Smith 1968). Priegel and Wirth 1975 said a lake sturgeon population never recovers from overfishing, but this conclusion was not supported by Sunde 1961. In the Mississippi Valley habitat changes may have kept the populations from recovering. Trautman 1957 attributed the decline of lake sturgeon in Ohio to blockage of spawning runs by dams, destruction of spawning habitat by siltation, pollution and drainage, and decline in the food supply (molluscs), as well as overfishing. Probably these factors were also important in the decline of the lake sturgeon elsewhere in the Mississippi Valley.

Habitat and Spawning

Lake sturgeon live in rivers and lakes, but the habitat varies with season and type of water. In rivers they prefer backwaters and areas along banks in the spring, and deep mid-river pools at other times (Kuehn et al. 1961, Haugen 1969). Seasonal movements to different habitats are

predictable (Jolliff and Eckert 1971). Young-of-the-year lake sturgeon have been found over gravel areas just below rapids (Priegel and Wirth 1971) and over shoals at the mouths of tributaries (Scott and Crossman 1973, Harkness and Dymond 1961). In lakes, the larger fish prefer shoal waters at depths between 4.6-9.2 m (Scott and Crossman 1973). Lake sturgeon feed over various bottom types (Trautman 1957, Harkness and Dymond 1961, Haugen 1969, Scott and Crossman 1973).

Spawning habitat has been described as steep-sided, rocky or boulder covered banks, below falls, and below dams where current is strongest (Dees 1961, Harkness and Dymond 1961, Priegel and Wirth 1971, Scott and Crossman 1973). In Wisconsin streams rip-rap composed of concrete slabs is preferred (personal communication 1979, John Klingbiel, Wis. Dept. of Nat. Res., Madison, Wisconsin). Walleye, white and longnose sucker, redhorse, and northern pike spawn in similar habitat (Harkness and Dymond 1961). Lake sturgeon have been reported to occasionally spawn on rocky, wave-swept shores of lakes (Eddy and Surber 1947, Scott and Crossman 1973, Priegel and Wirth 1971).

Present-day spawning areas for the lake sturgeon in the Mississippi Valley are not known. Certain rivers of Minnesota and Wisconsin that have long been important to the lake sturgeon (Cox 1897, Coker 1930), continue to support significant populations, indicating that spawning must occur there. These rivers were described by Kuehn et al. 1961. The large lake sturgeon harvests from the Osage River in Missouri suggest that this stream may have supported a spawning population prior to construction of Lake of the Ozarks.

Lake sturgeon spawn when water temperatures are between 13-18°C (Scott and Crossman 1973), generally between April 5 and mid-June in Minnesota

(Eddy and Surber 1947) and between late May and mid-June in southern Ohio (Trautman 1957). Spawning at any given locality continues for several hours or a few days (Scott and Crossman 1973), and is indicated by sturgeons rolling near the surface and making thumping sounds with their bodies (Folz 1979). During spawning the lake sturgeon is very sensitive to disturbances, which may cause abandonment of the area (Harkness and Dymond 1961). Jolliff and Eckert 1971 speculate that dams having waterfalls which might offer spawning habitat near population centers may not be used because of extensive human activity and disturbances.

Growth and Food

Lake sturgeon grow rapidly when young, but growth slows with age. By the first summer they average 12.3 cm total length (Scott and Crossman 1973). Lake sturgeon in Lake Winnebago, Wisconsin reportedly grow faster than those in Canadian waters (Royer, et al. 1968) and average 8.6 kg (112 cm) at 10 years and 17.7 kg (137 cm) at 20 years (Priegel and Wirth 1975). The growth rate of lake sturgeon in more southern waters is not known, but presumably would be faster.

Lake sturgeon mature at a relatively large size and old age, and males mature sooner than females. Males reach sexual maturity at 76-102 cm (T.L.) and 12-19 years of age; females are 84-120 cm (T.L.) and 14-23 years of age (Scott and Crossman 1978; Roussow 1957). Adult lake sturgeon spawn at intervals of 2-6 years rather than annually. The periodicity is less for males and increases with age for both sexes (Roussow 1957; Sunde 1961). The interval between spawnings is less in southern localities (Magnin 1966).

Lake sturgeon forage along the bottom. Mayfly nymphs, chironomid

larvae and molluscs were major components of the diet in Lake Nipigon, Ontario; fish were rarely ingested (Harkness 1923). However, in the St. Lawrence River, fish accounted for 24% of stomach contents (Vladykov and Greeley 1963, Jolliff and Eckert 1971), and small fish were a preferred bait for lake sturgeon (Vladykov and Greeley 1963, Reedstrom 1964, Haugen 1969, Jolliff and Eckhert 1971).

Movement

Lake sturgeon move considerable distances and are active through the winter. In the St. Lawrence River most tagged lake sturgeons were recaptured within 16 km of where they were tagged, but some moved as much as 160 km in 3 months (Magnin and Beaulieu 1969). Studies of related species (*A. transmontanus* and *A. brevirostrum*) showed movements of 3-16 km in a week and 193 km in 11 days (Haynes et al. 1978, Heidt and Gilbert 1978). McCleave et al. 1977 reported no diel differences in distance, speed, or straightness. Lake populations of lake sturgeon migrate up rivers 120 to 402 km to spawn (Smith and Van Oosten 1940, Priegel and Wirth 1971, Scott and Crossman 1973). Homing tendencies are reported, as well as some cases of fish wandering from lake to lake (Priegel and Wirth 1971, Scott and Crossman 1973).

Additional information and extensive bibliographies on the lake sturgeon can be found in Harkness and Dymond 1961, Magnin 1962, and Carlander 1969.

Importance to Man

Attitudes toward lake sturgeon have ranged from considering them a nuisance, to prizing them highly. Harkness and Dymond 1961 described the destruction of the lake sturgeon resource as among our worst, and

Sunde (1961) said "Nowhere have sturgeon been more depleted than in North America".

Sturgeon markets were developing in North America in 1860 and peaked by 1890. The populations were decimated after an additional 18 years in the Great Lakes and 10 years in Lake of the Woods (Smith 1914).

Lake sturgeon are now protected in many states. Sport harvest was permitted in Iowa, Illinois, and Missouri until the early 1970's, but has since been closed. The only remaining sport fisheries in the Mississippi drainage are in Wisconsin and Minnesota. Sport fisheries for lake sturgeon in the Mississippi River drainage of these states are restricted to the Mississippi River north of the Iowa boundary, the St. Croix River and its tributaries, and all inland rivers in Wisconsin. The more popular streams include the Snake and Kettle rivers in Minnesota, the St. Croix above Taylor Falls Dam (personal communication 1978 Joe Scidmore, Minn. Dept. of Nat. Res., St. Paul, Minnesota), and the Chippewa and lower Wisconsin rivers in Wisconsin (Becker in press).

The only available estimates of sport harvest of lake sturgeon are for the Mississippi River pools in three years, 1962-1963, 1967-1968, and 1972-1973 (Kline and Golden 1979a). Only 47 lake sturgeon were reported, all caught in Pool 4 in 1962. In 1979, one fisherman caught 300-400 lake sturgeon less than the 114 cm length limit from the Mississippi River below Dam 4 (personal communication 1979, Bruce Hawkinson Minn. Dept. Nat. Res., Welch, Minnesota).

In Wisconsin and Minnesota, harvest is regulated by 6 month seasons, a 114 cm minimum length limit, and limits of one fish per season (Wisconsin) and one in possession (Minnesota). These controls are similar to those

proved effective for Wisconsin sturgeon fisheries in the Great Lakes drainage (Priegel 1973, Priegel and Wirth 1975, 1978). Controlled harvest was also allowed in New York (Jolliff and Eckert 1971) until recently (personal communication 1980, Thomas Eckert, N. Y. Dept. Environ. Conserv., Cape Vincent, New York), and Canadian provinces still regulate limited harvests in the Saskatchawan and Nelson rivers (Sunde 1961, Royer et al. 1968, Haugen 1969). The largest stable harvest in North America is a spear fishery in Lake Winnebago, Wisconsin where annual exploitation is 4.7% (Priegel and Wirth 1975). Nearly all other states have classified the lake sturgeon as threatened or endangered (Guillory et al. 1978, Berger and Neuner 1979), and it is also considered to be threatened in Canadian waters (Deacon et al. 1979).

Artificial Propagation

Artificial propagation has been used in Russia to restore sturgeon stocks that were adversely affected by river alterations and other factors (St. George 1972; Khoroshko 1972; Gun'ko and Naumov 1965; Mageramov 1968). Since sturgeons have exacting spawning requirements, new hatchery technologies had to be developed. There is interest in the potential of artificial propagation for maintaining sturgeon stocks in the U.S., but the techniques for accomplishing this are still largely undeveloped. Culture programs are under development for the Atlantic sturgeon (U. S. Fish and Wildlife Service 1979a; Murawski and Pacheco 1977) and the green sturgeon and white sturgeon of the Pacific Coast (Psycha 1956; White 1978; Semakula and Larkin 1968; personal communication 1979, Serge Doroshov, Univ. of Calif., Davis, California). Early attempts to culture lake sturgeon were largely unsuccessful

(Leach 1920; Harkness and Dymond 1961). In 1979, Wisconsin biologists obtained 85% survival to the fry stage for eggs obtained by ceasarean section, but survival to the fingerling stage was low (personal communication 1979, John Klingbiel, Wisc. Dept. Nat. Res., Madison, Wisconsin). Artificial propagation may offer the greatest potential for reestablishing and enhancing lake sturgeon populations in areas where spawning habitat has been destroyed or substantially reduced.

Status and Threats to Survival

Lake sturgeon are extremely rare in Missouri today. All of the lake sturgeon reported in the last several decades have weighed more than 6.8 kg, suggesting that they are migrant fish produced outside of Missouri. Possibly they were produced in tributaries of the Upper Mississippi River in Minnesota and Wisconsin, where the largest populations of this species are presently found. If those populations persist at present levels, and no additional barriers to dispersal are erected, lake sturgeon will likely persist in Missouri at the present low levels. These low levels appear to result from increased mortality due to man's activities and the loss of spawning habitat. The protection from fishing pressure afforded to the lake sturgeon in recent years has thus far had no measurable effect on population levels.

PALLID STURGEON

Distribution and Abundance

The pallid sturgeon occurs in the Missouri River from near its junction with the Yellowstone River in Montana to its mouth near St. Louis, Missouri, and in the Mississippi River from the mouth of the Missouri to New Orleans,

Louisiana (Bailey and Cross 1954). It is confined primarily to the Missouri-Mississippi mainstream, but occurs occasionally in the downstream sections of large tributary streams, such as the Kansas and Platte rivers. The pallid sturgeon also formerly occurred in the upper Mississippi River at least to the mouth of the Illinois River (Forbes and Richardson 1905). A report of this species from the Mississippi River near Keokuk, Iowa by Coker 1930 is not supported by specimens. There are no recent records for the pallid sturgeon in the Mississippi River above the mouth of the Missouri.

The pallid sturgeon was not recognized as a species until it was brought to the attention of ichthyologists by Mr. Ashlock, a commercial fisherman at Grafton, Illinois (Forbes and Richardson 1905). At the time of its original description, the pallid sturgeon was reported by Mr. Ashlock to comprise one in 500 (2%) of the river sturgeons captured by him in the Mississippi River at Grafton, Illinois. Mr. Ashlock reported that the pallid sturgeon was more abundant in the Lower Missouri River near West Alton, Missouri, where it comprised one-fifth (20%) of the river sturgeons captured. Bailey and Cross 1954 provided additional information on the proportions of pallid sturgeon in the total catch of river sturgeons from various parts of the species range, as follows: Kansas River at Lawrence, 8%; Missouri River of South Dakota, 3 (5%) of 62 specimens; and Mississippi River at New Orleans, 3 (75%) of 4 specimens. Fisher 1962 recorded 4 (31%) of 13 river sturgeons from the Missouri River in Missouri as pallid sturgeon. His collections were made in 1945. In more recent studies, Gould and Schmulbach 1973 recorded 1 pallid sturgeon (0.02%) out of more than 6,399 river sturgeons from the Missouri River between Gavins Point Dam and Rulo, Nebraska, Moos 1978 recorded 1 pallid sturgeon (0.02%) out of more than 4,800 river sturgeons

in the Missouri River where it borders Clay County, South Dakota, and Kallemeyn and Novotny 1977 reported 1 pallid sturgeon (0.4%) out of 248 river sturgeons from the Missouri River downstream from Fort Randall Dam in South Dakota.

In the present study, 11 (0.3%) of 4,062 river sturgeons from the Missouri and Mississippi rivers were identified as pallid sturgeon (Table 1). These specimens were collected from 6 of the 13 areas sampled (Fig. 3). Five of these 11 specimens (45.5%) came from Cairo, where the pallid sturgeon comprised 2.7% of the river sturgeon captured. The proportion of pallid sturgeon in collections from other areas where this species was captured were: Brownsville -- 0.5%, St. Joseph -- 1.5%, Kansas City -- 0.3%, Easley -- 0.2%, and Ste. Genevieve -- 1.0%. No pallid sturgeon were captured from the two areas sampled on the Upper Mississippi River (Canton and Saverton), nor from Waverly, Brunswick, or St. Louis on the Missouri River, and Chain of Rocks and Caruthersville on the Middle and Lower Mississippi River.

The results of this study suggest that the pallid sturgeon is presently rare but widely distributed in the Missouri River and the Mississippi River downstream from the mouth of the Missouri, and perhaps is slightly more common in the Mississippi River near Cairo than elsewhere. This species apparently is absent or very rare in the Mississippi River upstream from the Missouri River. The information gleaned from the literature on the relative proportions of pallid sturgeon in the total catch of river sturgeon over the period from 1900 to the present suggests a probable decline in abundance of this species. The reports by Mr. Ashlock concerning the abundance of pallid sturgeon in the Lower Missouri and adjacent Mississippi

River seem particularly significant in this regard. The present occurrence of the pallid sturgeon in that area is not documented by our collections, although it doubtless is still present in small numbers. However, if it still comprised a fifth of the river sturgeons captured in the lower Missouri River, as reported by Mr. Ashlock, it should have occurred among the 148 river sturgeons in our catch from the lower Missouri River, and the 1684 river sturgeons in our catch from the Mississippi River at Chain of Rocks just downstream from the mouth of the Missouri River. It may also be significant that recent sampling of river sturgeons from within the range of the pallid sturgeon (Gould and Schmulbach 1973, Moos 1978, Kallemyn and Novotny, 1977 and the present study) have resulted in catches of pallid sturgeon comprising 0.02-2.7% of the sturgeons captured, whereas the sampling done prior to 1955 (Bailey and Cross 1954 and Fisher 1962) resulted in catches of pallid sturgeon in the range of 5% to 31% (in the small sample from New Orleans 75%) of the total river sturgeon sample.

Habitat and Associated Species

The pallid sturgeon lives in a strong current over a firm sand bottom in the channels of large rivers (Bailey and Cross 1954). The current in these areas was often swifter than that preferred by the shovelnose sturgeon (Forbes and Richardson 1920). However, this species has also been collected from some of the reservoirs on the Upper Missouri River in the Dakotas (Sprague 1960). In the reservoirs, they were captured at depths up to 24.5 m (personal communication 1979, Dennis Unkenholz, S. D. Dept. Game, Fish, and Parks, Yankton, South Dakota).

Pallid sturgeon caught during this study were usually taken with shovelnose sturgeon, but sometimes were caught in areas with strong currents

where shovelnose sturgeon were less numerous. Each gear-set that yielded a pallid sturgeon contained on the average two shovelnose sturgeon. Velocities near the bottom of the river where pallid sturgeon were caught ranged from 0.03 m/sec to over 0.73 m/sec. Depth in these same areas ranged from 1.2-13.8 m. On two occasions, two pallid sturgeons were caught on the same trot line on successive days. This occurred in a collection by us in the Lower Mississippi River at Cairo, and a collection by a commercial fisherman in the Middle Missouri River section.

Pallid sturgeon were taken in association with many big-river fish species. Shovelnose sturgeon, blue catfish, and river carpsucker were the species most frequently captured with the pallid sturgeon. As noted by Bailey and Cross 1954 the habitat and distribution of the sicklefin chub (*Hybopsis meeki*) is very similar to that of the pallid sturgeon.

Food

Relatively little information is available on the food habits of pallid sturgeon. Cross 1967 reported that the stomach of a pallid sturgeon from the Kansas River contained larval insects and small fishes. In the present study, fish and larval trichopterans each comprised 38% of the stomach contents of pallid sturgeon (Table 2). Other aquatic insects comprised the bulk of the remaining stomach contents (18%). The pallid sturgeon appears to consume greater quantities of fish than the shovelnose sturgeon. In river sturgeons larger than 61 cm T.L. we found a significant difference between the pallid and shovelnose sturgeons in the quantities of fish consumed ($t = 4.92$, $df = 69$). A reputed pallid sturgeon from the Mississippi River near Keokuk Dam contained 90% fish (Coker 1930). Some

authors (Smith et al. 1971; Bailey and Cross 1954) doubted Coker's identification because his record is outside the presently known geographic range of the pallid sturgeon, but we believe his findings concerning diet lend support to his identification.

Size, Age, and Growth

The pallid sturgeon attains a substantially greater size than the shovelnose sturgeon. Bailey and Cross 1954 examined a specimen that measured 1,473 mm (58 in) and weighed 14.3 kg (31.5 lb), and called attention to a 21.4 kg (47 lb) specimen reported by Cope 1879. An even larger specimen reported by Bailey and Allum 1962 weighed 30.9 kg (68 lb). Brown 1971 mentioned unconfirmed reports by commercial fishermen of specimens over 45.5 kg (100 lb). No pallid sturgeon approaching these sizes were found in the present study. Our specimens ranged from 480-895 mm in length and 0.36 to 2.66 kg in weight. We obtained verbal reports from commercial fishermen of two specimens that each weighed more than 13.6 kg (30 lb).

Eight pallid sturgeon were aged, using techniques developed and validated for shovelnose sturgeon (Helms 1974b). Their rate of growth was significantly more rapid than for shovelnose sturgeon ($t = 4.77$ $df = 6$) of the same age. Both species achieved an age of at least 14 years (Fig. 4). The growth of six pallid sturgeon in South Dakota was also more rapid than for shovelnose sturgeon from the same waters (Fogle 1963).

Reproduction

Little is known about this aspect of the life history of the pallid sturgeon. In South Dakota, males mature at a length of 530-580 mm (Fogle

Table 2. Average estimated volume (ml/fish) of food items in stomachs of adult river sturgeons.

Sturgeon group	Average length (cm)	Number of stomachs	Odonata	Ephemeroptera	Trichoptera	Diptera	Mollusca (shell)	Fish	Plant material	Other	Total
Pallid	67.0	9	.13(9)	.09(6)	.55(38)	.04(3)	.01(1)	.55(38)	.04(3)	.03(2)	1.44(100)
Shovelnose	65.2	62	.03(6)	.08(16)	.23(46)	.07(14)	T(T)	.01*(T)	.01(2)	.10(16)	0.53(100)
Hybrid	61.6	6	.11(6)	.33*(16)	.10(4)	.08(4)	.05(2)	.63(31)	.56*(27)	.21(10)	2.07(100)

* Significantly different from values (as ml/fish) for other groups of sturgeons.

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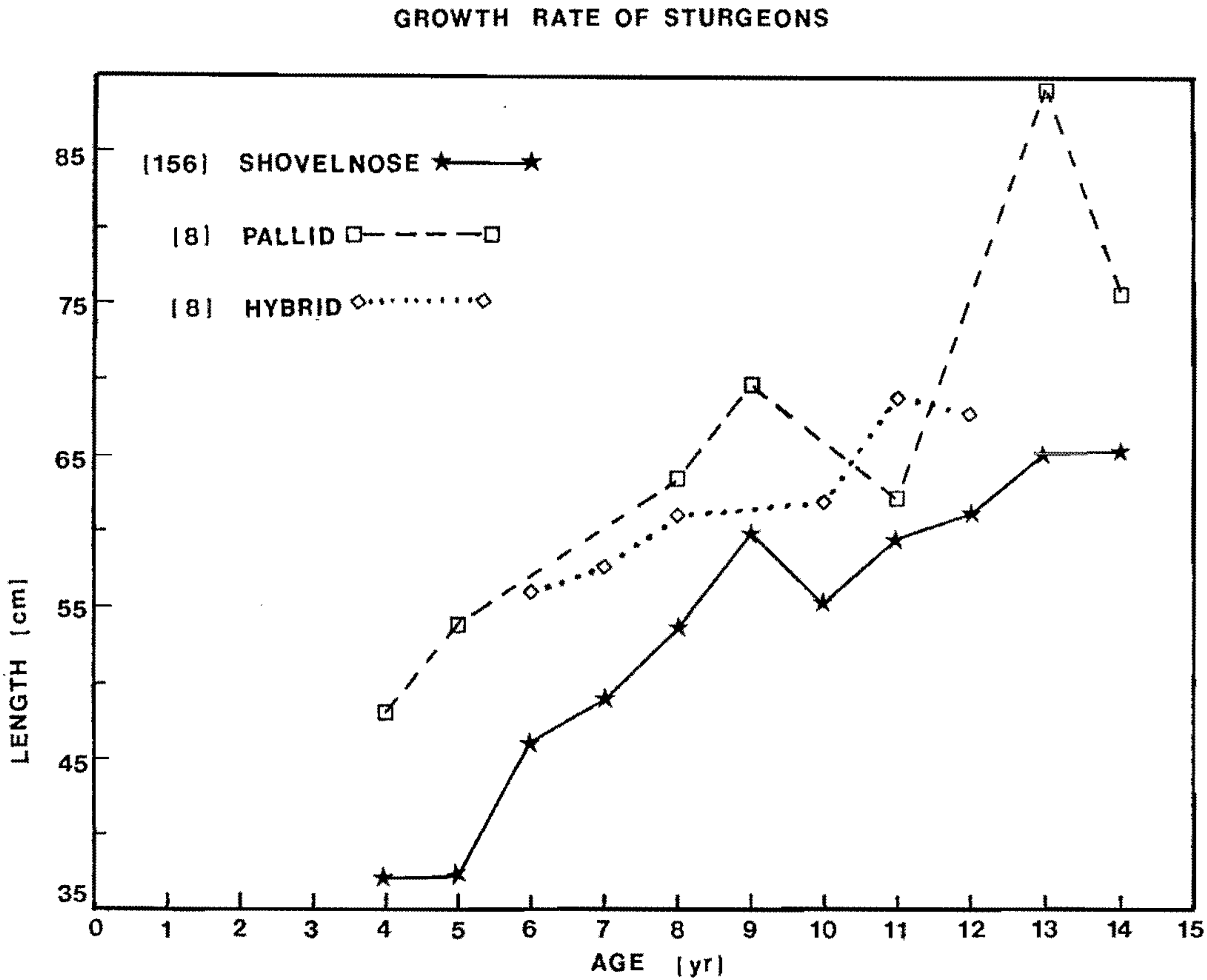

Figure 4. Average back-calculated length at each annulus of 172 river sturgeons in the Missouri and Mississippi rivers.

1963b). The sex ratio of females to males in our collections was 2:1. Forbes and Richardson 1920, reported spawning in June and July. Nothing is known of the spawning habits and habitat.

Status and Threats to Survival of the Pallid Sturgeon

The present rarity of the pallid sturgeon throughout its range is well documented. The early abundance of the pallid sturgeon is not known, but the available information on the proportions of pallid sturgeon in the total catch of river sturgeons over the period of record (1900 to present), suggests a decline in relative abundance of this species. Commercial fishery records clearly suggest a decline in abundance of river sturgeons, and it seems reasonable to conclude that the pallid sturgeon has undergone a drastic and potentially serious decline during this period. Small pallid sturgeon (<2.3 kg) have been rarely caught in recent years in Montana, causing concern for survival of the species (personal communication 1979, Al Elser, Montana Fish and Game, Miles City, Montana).

The documentation of apparent hybridization between the pallid sturgeon and the shovelnose sturgeon (see next section) is one of the most significant findings of this study, because it has important implications for the prospects of long-term survival of this species. The pallid sturgeon is largely restricted to the Missouri-Mississippi mainstream, and is sympatric with the more abundant and widespread shovelnose sturgeon throughout its range. Hybridization with the shovelnose sturgeon would be detrimental to the pallid sturgeon because of the loss of reproductive potential (gametes) and more importantly because of the possibility of genetic swamping through introgression. Such introgression could lead to eventual elimination of

the pallid sturgeon within the area of hybridization.

HYBRIDS, IDENTIFICATION AND DOCUMENTATION

Fifteen of 4,062 river sturgeons examined during this study were tentatively identified as hybrids between the pallid sturgeon and the shovelnose sturgeon. Identification of these specimens as hybrids was based on the intermediate condition they exhibited in characters (barbel alignment and length, head length, belly scutellation) used to separate the two species of river sturgeons. Specimens of the presumed hybrids and the parent species were subjected to morphometric, meristic, and biochemical comparisons to substantiate or refute this preliminary conclusion.

Morphometric and Meristic Comparisons

Thirty river sturgeons ranging in standard length from 447 mm to 816 mm were used in this comparison. The presumptive identifications of these specimens were: 10 shovelnose sturgeons, 8 pallid sturgeons, and 12 hybrids.

In Table 3, the specimens are arranged from left to right in the order specified by the Character Index (see methods section for an explanation of the Character Index). There was close agreement between the field identifications (last line of Table 3) and the order specified by the Character Index (next line above). Except for specimens 4 and 24, all those identified in the field as hybrids were intermediate in the Character Index between specimens identified in the field as platorynchus or albus.

The Character Indices are graphed for visual comparison in Figure 5A. Specimens identified in the field as platorynchus and albus do not overlap in the Character Index, but the specimens identified as hybrids span the

gap between the ranges of "platorynchus" and "albus".

To provide some perspective for interpreting these results, we computed the Character Index for proportional measurements of 15 specimens studied by Bailey and Cross 1954, Table II. For their data, the index could be computed only for proportional characters. Their specimens (Fig. 5C) are clearly separated into two distinct groups, corresponding according to their identification to platorynchus and albus. The Character Indices for proportional characters of specimens in the present study (Fig. 5B) exhibit no clear separation into groups. Rather, they exhibit a pattern comparable to that for all characters combined (Fig. 5A), but with a slightly more overlap between specimens identified as hybrids and those identified as the parental types. The distribution of the Character Index appears comparable between specimens identified as S. platorynchus and S. albus in the present study and the specimens studied by Bailey and Cross 1954. However, most of their specimens were smaller than those in the present study, and their smallest specimens exhibited the most intermediate values. Perhaps the separation between the two species would have been even greater for their data if larger specimens had been available.

The results obtained in this analysis provide substantial support for the field identification of Scaphirhynchus recently collected from the Missouri and Mississippi rivers as hybrids. These specimens are intermediate between other specimens identified as S. platorynchus and S. albus. Intermediacy is indicated for individual characters (Table 3) and for a Character Index which expresses how each specimen compares with every other specimen in the composite of the characters studied.

Table 3. Counts and measurements of 30 specimens of *Scaphirhynchus* collected from the Missouri and Mississippi rivers in 1978 and 1979. Specimens are arranged from left to right in the order specified by the Character Index.

Specimen #	41	55	51	50	54	53	17	16	4	15	13	12	14	38	26
Standard Length (mm)	808	554	509	536	573	620	551	561	517	612	476	618	561	551	639
Fin Rays															
Dorsal	31	30	31	32	29	35	31	34	34	37	34	37	32	42	37
Anal	20	20	18	21	19	21	20	20	23	23	21	23	21	24	22
Pectoral	41	32	49	44	42	41	38	41	38	43	38	49	46	47	45
Pelvic	24	22	31	27	25	28	26	28	25	29	28	29	26	27	27
Measurements (Thousandths of Standard Length)															
Head Length	251	256	260	256	267	265	267	263	277	250	288	242	307	265	285
Rostral Length	175	154	183	174	190	176	185	180	203	167	206	181	217	185	200
Orbit Length	13	5	12	14	12	6	8	8	14	6	13	12	14	12	12
Mouth Width	74	74	71	74	76	72	75	77	79	73	84	74	85	85	81
Inner-barbel Length	48	65	65	58	65	65	58	68	70	69	64	62	66	65	63
Outer-barbed Length	62	96	91	73	83	93	74	90	91	100	84	90	91	105	102
Mouth to Inner Barbel	50	65	61	58	57	66	61	68	71	59	61	54	66	58	58
Snout to Outer Barbel	102	99	91	98	103	93	109	100	106	102	105	92	130	112	124
Tenth Lateral Plate Height	52	[illegible]	54	47	41	52	46	41	38	51	43	42	39	40	41
Character Index	212	284	295	295	316	334	339	347	348	393	414	420	479	481	511
Field Identification	P	P	P	P	P	P	P	P	H	P	P	H	H	H	H

Specimen #	21	25	40	23	30	3	27	24	7	28	11	10	1	29	6
Standard Length (mm)	578	600	620	539	631	592	572	610	586	680	447	503	686	691	816
Fin Rays															
Dorsal	38	38	39	39	39	39	37	37	41	37	36	39	41	39	37
Anal	24	25	25	25	23	23	24	24	25	22	24	26	26	24	25
Pectoral	51	42	45	51	46	43	47	46	40	43	49	52	51	42	44
Pelvic	29	29	27	29	28	27	31	32	30	28	32	31	32	30	30
Measurements (Thousandths of Standard Length)															
Head Length	277	278	269	289	281	302	283	301	285	306	295	306	296	313	317
Rostral Length	194	197	187	202	187	206	205	208	191	201	213	207	197	213	216
Orbit Length	11	12	11	12	9	11	10	9	8	10	14	11	5	-	9
Mouth Width	81	87	95	87	87	94	80	85	99	100	79	91	101	103	92
Inner-barbel Length	63	60	72	64	59	69	49	68	60	52	60	51	78	61	42
Outer-barbed Length	92	103	119	96	102	130	80	122	116	131	86	97	149	155	103
Mouth to Inner Barbel	60	60	54	57	57	59	53	56	57	59	39	51	58	59	51
Snout to Outer Barbel	118	121	115	123	127	123	130	137	132	136	122	138	128	134	146
Tenth Lateral Plate Height	43	41	39	37	38	42	40	39	39	35	32	35	35	30	33
Character Index	535	548	561	583	586	593	630	638	670	676	679	770	781	793	796
Field Identification	H	H	H	H	H	H	A	H	A	A	A	A	A	A	A

P = *platorynchus* H = Hybrid A = *albus*

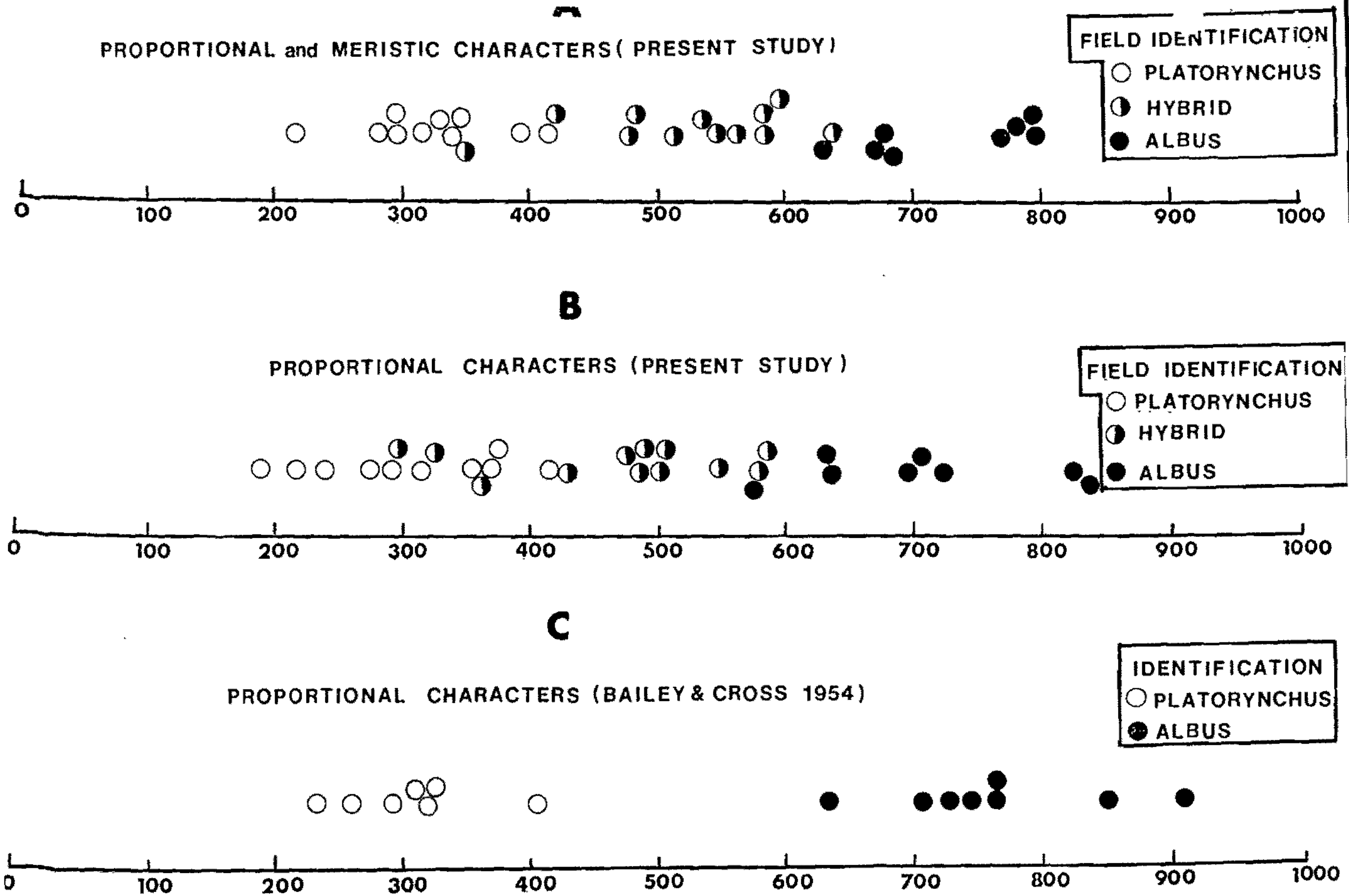

Figure 5. Character Indices (average of 9 proportional and 4 meristic characters) for specimens of Scaphirhynchus collected in 1978 and 1979 (present study), and prior to 1954 (computed from data presented by Bailey and Cross 1954, Table II).

Biochemical Comparisons

Biochemical analysis (electrophoresis) of sturgeon tissue, using procedures described by Allendorf et al. 1977 and May et al. 1979, was used in an attempt to further analyze hybridization. Comparisons were made of 10 pallid sturgeons, 74 shovelnose sturgeons, and 6 presumed hybrids.

Tissues from pallid sturgeon, shovelnose sturgeon, and presumed hybrids were identical at all 52 loci examined (Phelps and Allendorf 1979). Also, at three polymorphic loci, the pallid sturgeon and shovelnose sturgeon, and geographically separated populations of the latter species, exhibited no statistically significant differences in morph frequency. These results provided no supportive evidence for or against the identification of our specimens as hybrids. The similarity at such a large number of loci does suggest a close genetic relationship between the pallid sturgeon and the shovelnose sturgeon. This result is surprising, considering the many phenotypic differences between the species.

Distribution and Habitat

Sturgeons identified as hybrids were collected from four of our study areas, but the most specimens (9) were obtained at Chain of Rocks on the Mississippi River. The numbers of specimens from other areas were: Kansas City (3), and St. Louis (2) on the Missouri River; and Cairo (1) on the Lower Mississippi River.

Based on capture data, the hybrids appeared to be more closely associated with the shovelnose sturgeon than with the pallid sturgeon. On the average, each gear-set that caught a hybrid contained 14 shovelnose sturgeons, compared with an average of two shovelnose sturgeons for gear-sets that caught pallid sturgeons.

Food, Growth, and Sex Ratio

The diet of hybrid sturgeon resembled that of the pallid sturgeon in that fish comprised about 1/3 of the volume of stomach contents (Table 2). Hybrids contained a significantly greater volume of plant material than either parent species ($t_{h-s} = 3.4$, df = 66; $5_{h-p} = 2.80$, df = 13), and a significantly greater volume of ephemeropterans (t = 3.62, df = 66) than did shovelnose sturgeon.

The growth rate of the hybrids was intermediate between that of the pallid sturgeon and the shovelnose sturgeon (Fig. 4).

The hybrids examined were all females (Appendix 4). The eggs of female hybrids were similar in size and appearance to those of the parent species.

Factors Favoring Hybridization

Comparison of data from this study with data reported by Bailey and Cross 1954 for specimens collected more than 25 years ago indicates that this hybridization is a recent phenomena, suggesting a fundamental and recent change in the behavioral and ecological relationship between these species. This fundamental change may be related to recent man-induced modifications of the big-river environment, which include reductions in habitat diversity and measurable changes in environmental parameters such as turbidity, flow regimens and substrate types. Schmulbach 1974 in studying suspected hybridization between sauger and walleye in the Missouri River, South Dakota has noted that hybridization between species is limited to places where man or nature has "hybridized the habitat". He concluded that the Missouri River, with its large mainstem reservoirs and channelized main stream, is such a hybridized habitat. His remarks concerning channel-

ization could apply as well to the Mississippi River where we found hybrid sturgeons.

SHOVELNOSE STURGEON

Distribution and Abundance

The shovelnose sturgeon occurs in large rivers throughout the Mississippi Valley. It formerly occurred in the Rio Grande River, but has not been taken there in this century (Bailey and Cross 1954). A closely related form in the Alabama River System is currently under study (Lee 1980). The range and abundance of the shovelnose sturgeon in the Mississippi Valley has been reduced by impoundments, overfishing, and pollution of streams (Bailey and Cross 1954). In Missouri, the shovelnose sturgeon occurs throughout the Missouri and Mississippi rivers and the lower stretches of their major tributaries (Pflieger 1975). There is no evidence that its range in Missouri is substantially different than it was in prehistoric times.

The abundance of shovelnose sturgeon has been estimated for a few river reaches. These estimated numbers were: 2,500/km for the unchannelized Missouri River in South Dakota (Schmulbach 1974); 1,030/km for navigation pools of the Mississippi River in Iowa (Helms 1974a); 403-537/km for the Tongue River, Montana (Elser et al. 1977); and 100/km for the Red Cedar-Chippewa River system,Wisconsin (Christenson 1975).

Shovelnose sturgeon sometimes occur in greater numbers than any other species in fish samples from the main channel of the Missouri and Mississippi rivers (Moos 1978, Helms 1974a). In our collections, shovelnose sturgeon comprised 73% of all fishes. Catch rates were highest (106 sturgeon/gear

day) at Chain of Rocks on the Mississippi River, and lowest (17 sturgeon/gear day) at Cairo on the Mississippi River. Catch rates at Saverton on the Upper Mississippi River were 36 sturgeon/gear day, a rate comparable to that on the Missouri River at Brownsville (38 sturgeon/gear day) and Easley (39 sturgeon/gear day). River carpsucker, freshwater drum, channel catfish, and blue catfish occurred in about equal numbers in our samples, and together comprised nearly 65% of the other fish species taken with the shovelnose sturgeon.

Commercial harvest reports serve as indicators of trends in abundance of the river sturgeons over the period of record, but have limitations with regard to their value in making comparisons in abundance between rivers and river sections. The harvest may more accurately reflect such factors as variations in fishing conditions, the number of fishermen, changes in regulations, and the marketability of the catch than any real differences in sturgeon abundance. Records of sturgeon harvest are available for 1894, 1899, 1922, 1931, and 1946 to the present (Smith 1898, Townsend 1902, Sette 1925, Fiedler 1933 and 1940, and Fisheries Statistics of the United States 1950-1975).

The harvest of river sturgeons (presumably mostly shovelnose sturgeon) increased in the late 1800's, perhaps in response to decimation of stocks of lake sturgeon. Prior to that time the shovelnose sturgeon was held in low esteem by fishermen, and those caught incidentally while fishing for more valued species were commonly discarded on the bank (Coker 1930, Helms 1974a, Carlander 1954). The total harvest of river sturgeons in the U.S. was 340 T in 1894; decreased to 36 T in 1931; and increased to about 84 T in the mid-1950's. For the last 10 years, the harvest has averaged about 23 T/year. The greatest harvests were from the Mississippi River (58%),

and the Wabash and Ohio rivers.

The commercial harvest in Missouri exhibited trends comparable to those for the U.S. as a whole. In 1899 the reported harvest for Missouri was 34.5 T; decreased to 7.8 T by 1931; and has been under 4.5 T each year since 1947. Most years, more than 80% of the river sturgeon were harvested from the Mississippi River, with the bulk of these coming from the Upper Mississippi River. The reported harvest from the Missouri River has been less than 0.5 T most years since 1960. An apparent increase in the reported harvest in recent years is the result of more complete reporting by commercial fishermen. During the 3-year period 1976-1978, the reported annual harvest ranged from 0.54 T - 9.94 T for the Missouri River and 2.62 T - 3.84 T for the Mississippi River. These figures may more accurately reflect the harvest than those for earlier years, when the reporting requirements for commercial fishermen were less stringent.

Habitat

The shovelnose sturgeon occurs in strong current of the river channel, usually over a bottom of sand or gravel (Bailey and Cross 1954). In the unchannelized Missouri River, this species prefers deep water behind sand bars in spring and fall, but disperses more widely during the warm summer months (Schmulbach et al. 1975). In the Tongue River, Montana it was reported to prefer a depth of 0.4-0.9 m in spring and early summer (Elser et al. 1977), and in the Missouri River it preferred a current velocity of 0.5-0.8 m/sec. (U. S. Fish and Wildl. Serv. 1979b). In the channelized Missouri River, shovelnose sturgeon congregate along sand bars on the inside of river bends and behind wing dikes with deeply scoured trenches.

Following the construction of impoundments on the Upper Missouri River, the abundance of shovelnose sturgeon declined, and growth slowed (Sprague 1961, Scalet and Peterka 1978). Impoundments on the Mississippi River were smaller and had less effect on shovelnose sturgeon populations, but the species is thought to be less abundant than before impoundment (Helms 1974a). However, substantial populations of shovelnose sturgeon still exist in these river-lakes. Schmulbach et al. 1975 reported that most fish species were less abundant in the channelized than in the unchannelized Missouri River, but the difference was especially noticeable for the shovelnose sturgeon.

Spawning habitat for the shovelnose sturgeon has not been documented. Forbes and Richardson 1920 thought that this species ascended smaller streams to spawn, but other workers have suggested that spawning occurs in the main channel of the Missouri and Mississippi rivers and their larger tributaries. Circumstantial evidence for spawning (capture of adults in breeding condition) has been interpreted as evidence for spawning in the Tongue River, Montana (Elser et al. 1977), the Chippewa River, Wisconsin (Christenson 1976), the Missouri River, South Dakota (Moos 1978; June 1976) and the Mississippi River, Iowa (Coker 1930; Helms 1974a). Spawning is thought to occur in swift water of the river channel (Coker 1930; Eddy and Surber 1947; Moos 1978).

The habitat of larval shovelnose sturgeon is not known, but young-of-the-year have been collected in the main channel of the river, a habitat similar to that occupied by the adults (Helms 1974a; Moos 1978; Pflieger 1975; personal communication, John Conner, Louisiana State University, Baton Rouge, Louisiana). June 1976 noted the absence of young-of-the-year

river sturgeons in the Upper Missouri River following impoundment of Lake Oahe. Walburg 1977 attributed a decline in the shovelnose sturgeon after construction of Lake Francis Case on the Upper Missouri River to loss of riverine spawning habitat.

Food

In the unchannelized Missouri River, South Dakota, the shovelnose sturgeon fed opportunistically on benthic invertebrates (principally larval aquatic insects) and exhibited three seasonal patters of: utilizing drift in fall months, utilizing a greater variety of invertebrates in the winter months, and foraging on benthic insects in late spring and summer (Moode and Schmulbach 1977). Changes in feeding activity and ration biomass (lowest during the period May-September) were related to the effects of flow rates on prey vulnerability. In the Upper Mississippi River, Helm 1974a reported a high frequency of empty stomachs in the fall.

In this study, aquatic insect larvae, primarily Trichoptera, Diptera, and Ephemeroptera, comprised most of the diet of the shovelnose sturgeon (Fig. 6). Together these groups made up 65% by volume of the total diet. The trichopteran genus *Hydropsyche* occurred in more stomachs (Appendix 4) and constituted more biomass (13%) than any other food organism. Diptera and Ephemeroptera were of nearly equal importance, comprising 18% and 16% by volume, respectively of the diet. The most important dipterans were Chironomidae, Muscoidea, Tabanidae, and Ceratapogonidae. Important ephemeropterans were the burrowers *Pentagenia* and *Hexagenia*, the free-swimming *Baetis*, and the sprawlers *Pseudiron* and *Heptagenia*. All of these occurred frequently in the sturgeon stomachs, but the *Pentagenia* and *Hexagenia* were most important volumetrically because of their large size.

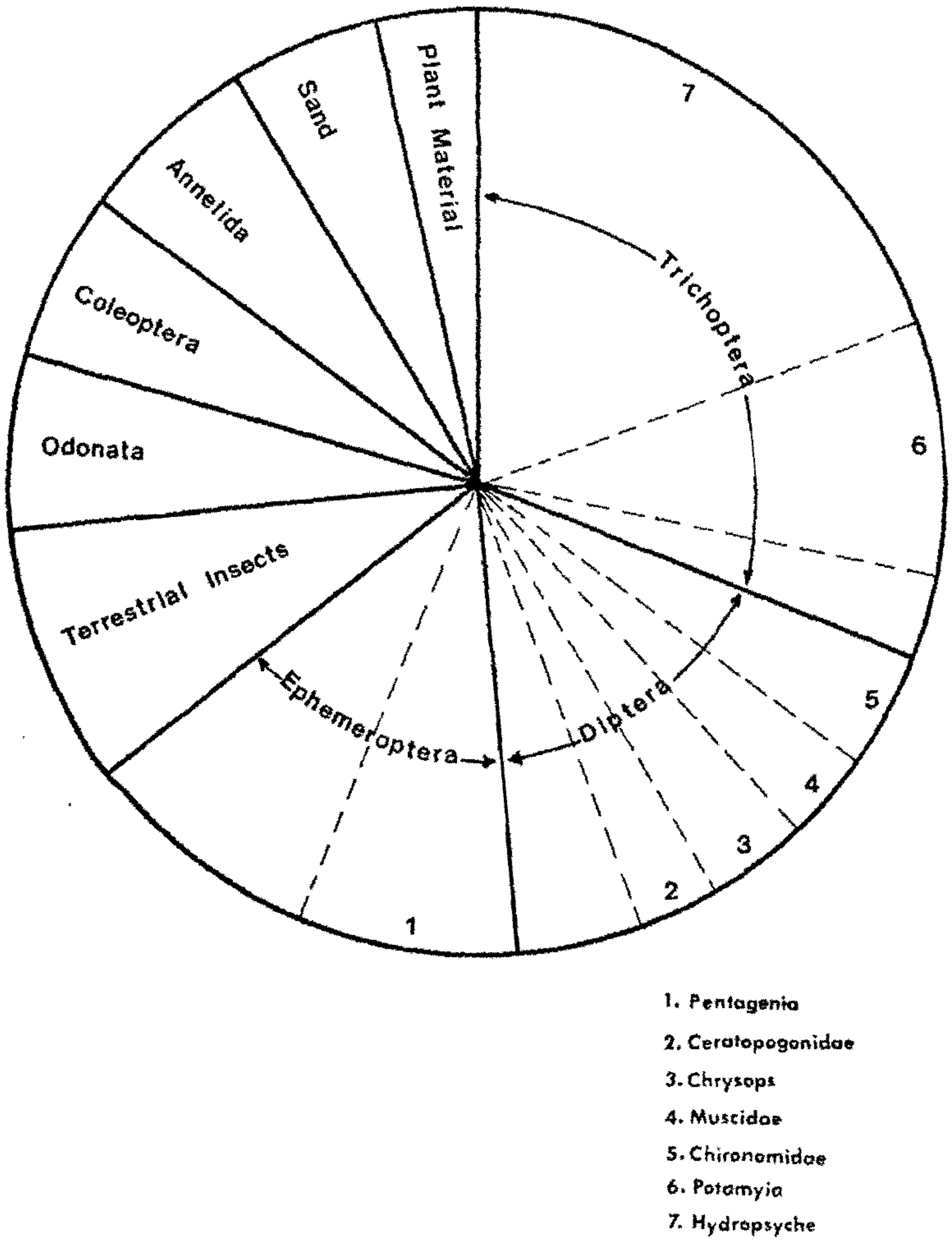

Figure 6. Percent composition by volume of items in the stomachs of 271 river sturgeons in the Missouri and Mississippi rivers.

Variations in diet of the shovelnose sturgeon were found between river sections, seasons, and fish sizes (Tables 4 and 5). In the Missouri River during spring, Diptera were predominant, followed by terrestrial insects, Coleoptera and Trichoptera. In the Upper Mississippi, Ephemeroptera were the principal food item during spring, followed by Diptera, Trichoptera, plant material, and terrestrial insects. Trichoptera were the predominant spring food item in the Middle and Lower Mississippi sections, with Ephemeroptera, Diptera, and Odonata occurring in lesser volumes.

During fall, Trichoptera were the most important food item in all river sections, and comprised 85% by volume of the diet of shovelnose sturgeon in the Middle and Lower Mississippi sections during fall. Ephemeroptera were nearly as important as Trichoptera in the Missouri River. Ephemeroptera, Annelida, and fish were of about equal importance in the Upper Mississippi during the fall season.

The diet changed with increasing fish size (Table 5). Small specimens (32.6-51.5 cm) consumed a significantly greater proportion of Diptera (t_{s-m} 3.20, df = 277; t_{s-l} = 1.69, df = 105, α = .10) than did larger sturgeons. Ephemeroptera became increasingly important in the diet with increasing fish size. Large sturgeons (77.6-89.5 cm) consumed significantly more fish than small sturgeons (t = 1.97, df = 105, α = .07). Their stomachs also contained significantly greater quantities of sand than the other two size groups (t_{l-n} = 2.08, df = 277; t_{l-s} = 2.04, df = 105).

Size, Age, and Growth

The maximum weight of the shovelnose sturgeon is generally considered to be about 3.2 kg (Cross 1967), but Elser et al. (1977) reported specimens

Table 4. Percent composition by volume of food items in stomachs of 271 shovelnose sturgeons in different seasons and river sections.

	Number examined	Terrestrial insects	Odonota	Plecoptera	Ephemeroptera	Trichoptera	Coleoptera	Diptera	Annelida	Fish	Plant	Sand
Spring												
Missouri	100	18.0	11.2	6.5	3.0	10.5	12.5	31.0	6.2	6.2	4.2	3.5
U. Miss.	83	5.8	1.6	1.2	32.0	9.7	1.0	13.6	-	-	7.0	8.2
M. Miss.	11	2.5	5.7	-	13.9	60.9	2.9	4.9	1.2	-	1.7	5.0
Fall												
Missouri	16	0.5	3.1	-	36.4	48.1	-	2.5	4.0	-	3.0	4.8
U. Miss.	32	1.0	4.0	-	11.0	52.0	1.5	5.7	12.0	12.0	0.4	11.0
M. Miss.	29	0.5	-	-	5.6	85.0	-	3.3	-	-	-	3.3

Table 5. Percent composition by volume of food items in the stomachs of shovelnose sturgeon of three length groups.

Length group (cm)	Number of stomachs	Terrestrial insects	Odonata	Plecoptera	Ephemeroptera	Trichoptera	Coleoptera	Diptera	Annelida	Fish	Plant	Sand
32.6-51.5	100	3.8	5.6	4.3	11.7	21.4	4.0	23.4	4.4	1.1	7.5	6.0
51.6-71.5	179	5.2	4.3	2.2	16.0	31.2	3.5	14.4	1.9	3.3	5.8	6.6
71.6-89.5	7	0.3	0.0	0.0	21.9	15.7	0.0	9.1	0.3	18.3	5.5	29.8

up to 5.9 kg. Evermann (1902) reported the average length and weight of this species in the Ohio River commercial harvest as 645 mm and 1.5 kg for females, and 551 mm and 0.9 kg for males. Barnickol and Starrett 1951 reported the average length and weight of this species in their samples from the Mississippi River as 589 mm and 0.6 kg, respectively. Elser et al. 1977 studied the size distribution of adult sturgeons in a spawning population in the Tongue River, Montana and reported an average length and weight of 752 mm and 2.48 kg in 1975 and 764 mm and 2.34 kg in 1976. They found that the average length of sturgeon from the Yellowstone River was 508 mm. Moos 1978 reported that over 99% of the 3,992 shovelnose sturgeon captured during his study on the Missouri River, South Dakota were over 450 mm fork length.

In this study, there appeared to be a progression in the size of the shovelnose sturgeon at stations on the Missouri River, with specimens at downstream stations being generally larger than those at stations from Kansas City upstream (Table 6). This is shown by the average length of specimens at each station, and even more distinctly by the percent of specimens over 50 cm and 60 cm. No consistent trend appears evident at stations on the Mississippi River, but specimens at all stations were on the average larger than those from the upper stations on the Missouri River. LeCren's Index (LeCren 1951), a condition factor that is less influenced by fish size than the ponderal index, was higher at all stations in the Missouri and the Middle and Lower Mississippi sections (except Chain of Rocks) than in the Upper Mississippi section. The length-weight relationship for all shovelnose sturgeon in this study is expressed by the equation $\log W_{10} = -3.056868 + 3.360871 \text{ Log } L$, when W is in grams and L

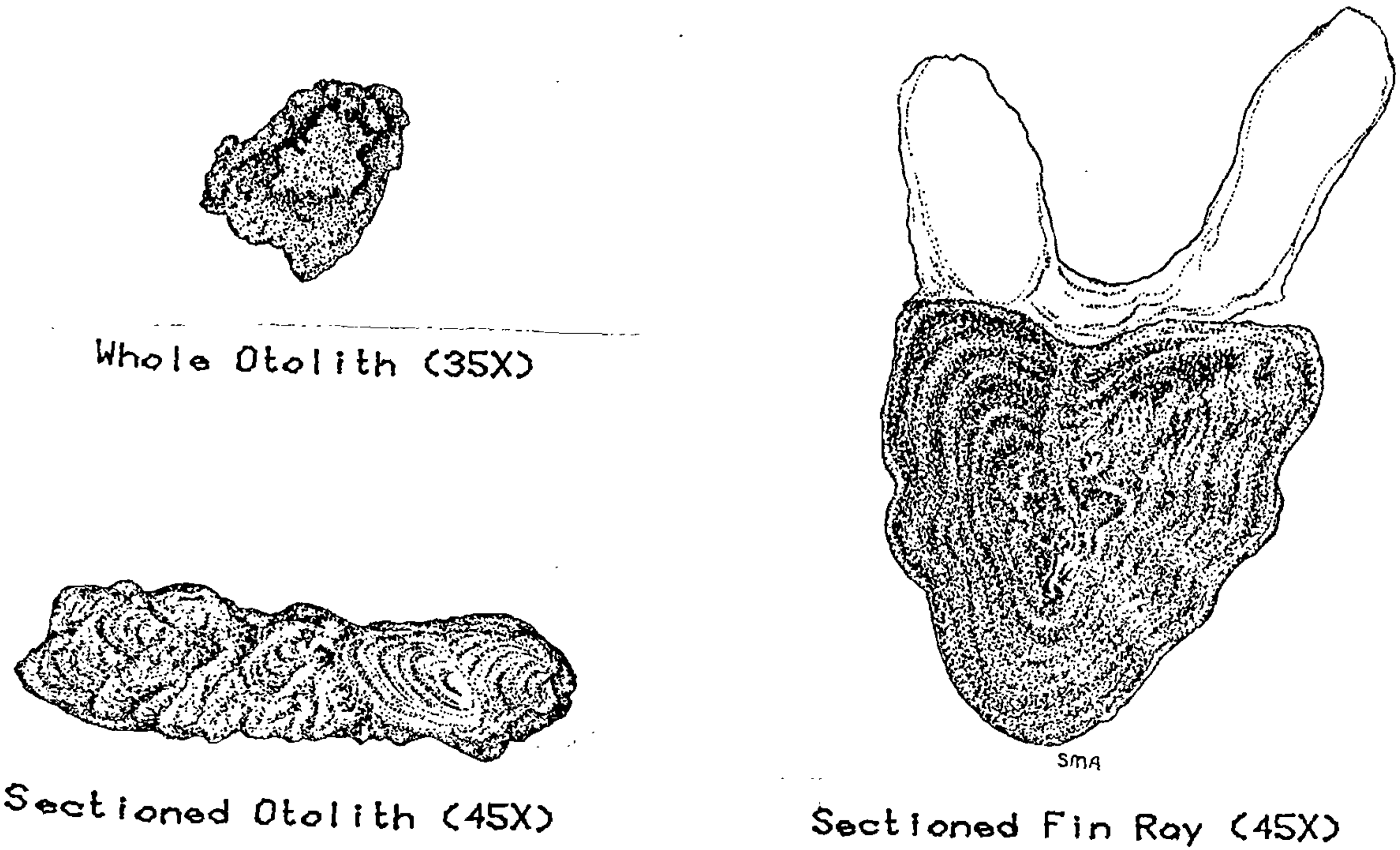

Figure 7. Aging structures of shovelnose sturgeons: fin ray section and otoliths section of the same fish.

Table 6. Comparison of length distribution and condition of shovelnose sturgeon from 12 sampling areas in the Missouri and Mississippi rivers.

	Missouri River					
	Brownsville	St. Joseph	Kansas City	Brunswick	Easley	St. Louis
Sample size	441	55	354	194	426	134
Mean length (cm)	47	48	50	50	51	58
% over 50 cm	30	42	47	56	63	83
% over 60 cm	1	5	3	8	14	41
LeCren's Index	1.05	1.00	1.09	1.08	1.01	1.03

	Mississippi River					
	Canton	Saverton	Chain of Rocks	Ste. Genevieve	Cairo	Caruthersville
Sample size	44	223	1,620	97	112	64
Mean length (cm)	53	52	54	57	58	54
% over 50 cm	73	56	74	82	89	69
% over 60 cm	150	12	26	32	56	39
LeCren's Index	0.95	0.96	0.96	1.06	1.14	1.15

Movement

Sturgeons can move great distances, but most of the year they are relatively sedentary. Previous tagging studies on the shovelnose sturgeon have all been from above dams, or below dams where upstream movement was restricted. Movements of shovelnose sturgeon in the Missouri River in South Dakota were described as seasonal, random in direction, and increasing in distance with time at-large (Moos 1978). In that study, 71% of the sturgeons tagged in spring moved more than 1.6 km, and the average distance for all fish was 4.5 km. Only 40% of the sturgeons tagged in summer moved more than 1.6 km, and the average movement was 0.8 km. Overall, most of the movements were within a 8-16 km stretch of river, except for a very few individuals that traveled 500-540 km (Moos 1978). In navigation pools of the Mississippi River, Helms 1974a reported that the average movement was 6.6 km and the greatest distance was 193 km. Interpool movement was documented for 9% of the fish, and these movements were always upstream. In the Chippewa and Red Cedar rivers in Wisconsin the average movement was 1.6 km (Christenson 1975) and the greatest distance was 35 km (Christenson 1979). In the Tongue River in Montana over 50% of the tagged sturgeon moved less than 1.6 km, but upstream movement was more common than downstream (Elser et al. 1977).

In Missouri, movement of 50 shovelnose sturgeons were greater than the movements reported in other studies. Spring movements for fish at-large for less than 6 months were greater than fall-winter movements, averaging 43 km and 3 km, respectively. Fish at-large more than 6 months had moved an average of 103 km. Approximately 40% of the fish were recaptured 10 km or more from where released. The furthest movement was 513 km, and the

fastest was 217 km in 34 days. Fish smaller than 50 cm moved shorter distances than larger fish, averaging 19 and 61 km, respectively.

Reproduction

Male shovelnose sturgeon reached sexual maturity at a smaller size than females, and the size at maturity seemed to vary between locations. In the Upper Mississippi River area, the smallest sexually mature females and males were 60-64 cm and 47-56 cm respectively (Monson and Greenbank 1947; Barnickol and Starrett 1951; Helms 1974a; Christenson 1975), while in the Missouri River the minimum sizes were 48 and 44 cm respectively (Moos 1978). The smallest mature females and males in the present study were 51 and 45 cm, and both came from the Missouri River. It is uncertain why such regional variation would occur.

Shovelnose sturgeon reach sexual maturity at 4-6 years of age (Helms 1974a), and spawn thereafter at intervals of 1-3 years (Moos 1978). They spawn over a period of less than a month in spring, when the water temperature is between 16.9-21.5°C (Elser et al. 1977; Christenson 1975). Spawning migrations have been reported in the Kansas River and its tributaries (Minckley 1959; Cross 1967). These migrations are greatest in years of high water. In the Missouri River, Missouri,ripe females were captured in mid-May (personal communication 1979, Jeff Johnson, Mo. Dept. Conserv., Malta Bend, Missouri). The number of eggs varies with body size, and a 1.4 kg female contained about 23,000 eggs (Helms 1974a).

According to Moos (1978), not all male shovelnose sturgeon spawn annually, and females spawn at intervals of 2 or 3 years. Helms 1974a reported similar observations. In the present study, 18% of the females

appeared to be ready to spawn in a given year, and 9% of the spring males were ripe. Perhaps many of the spawning adults had moved upstream out of our study area.

In samples collected prior to the spawning season, males predominated over females in both the Mississippi River (Barnikol and Starrett 1951) and the Missouri River (Moos 1978). In the present study, females outnumbered males almost 3:1 in samples collected during the spring spawning season. The low percentage of males during this period may imply an upstream spawning movement, with males preceding females to the spawning grounds.

Predation, Parasites, and Abnormalities

The shovelnose sturgeon may be most vulnerable to predation by fish or birds during the first two years of life when the scutes are not well developed, as indicated for a related species by Ginzburg 1972. Internal parasites previously reported in this species were two species of trematodes and one species of nematode (Hoffman 1967). Glochidia of the naiad *Obovaria olivaria* (listed as *Obovaria ellipsis*) were reported by Coker et al. 1921. In this study, leeches were commonly found attached to sturgeon. Perhaps these were *Placobdella montifera*, the only species listed in Hoffman 1967.

Body deformities such as stub tail, missing fins, and notched rostrums were observed in 2.5% of the shovelnose sturgeon that we examined. These were old wounds of unknown origin. Also, a few fish had one eye missing. These abnormalities were also noted on sturgeon in the Missouri River, South Dakota (Moos 1978) and the Yellowstone River, Montana (personal communication 1979, Larry Peterman Montana Fish and Game, Helena, Montana).

Rubber bands, plastic six-pack holders and oil gaskets encircled the heads of 0.2% of the sturgeons we captured.

Hermaphroditism occasionally occurs in sturgeons (Atz and Smith 1976, Maschkowzeff 1934). In Lake Oahe on the Upper Mississippi, hermaphrodites comprised 2.1% of the catch (June 1976), and in the unchannelized Missouri River in South Dakota hermaphrodites comprised 1.6% (Moos 1978). Three percent of the sturgeons in our catch were hermaphrodites.

Fisheries

Today, there are significant fisheries for shovelnose sturgeon in some areas. Most of the commercial harvest of shovelnose sturgeon (54%) comes from the Mississippi River above St. Louis (Fisheries Statistics of the U.S. 1950-1975; UMRCC Annual Reports). In Mississippi River pools in Iowa an estimated annual rate of exploitation of 18% was not judged excessive (Helms 1974a).

Most sturgeon from the Mississippi and Wabash rivers are sold in fish markets along the Upper Mississippi River and in Chicago. Prices received in 1974 averaged $0.20 to $0.48 per pound fresh, and $0.45-$2.25 per pound smoked (Helms 1974a).

Sport harvests in seven pools of the Upper Mississippi River for 1962, 1967, and 1972 ranged from 22 to 359 sturgeon/year (Kline and Golden 1979b). The most popular sport fisheries for sturgeon in the Missouri part of the Mississippi River are below Saverton (Dam 22) and at Chain of Rocks (Dam 27). The spring harvest from Saverton Dam tailwater in 1979 (a poor year) was only 52 sturgeon (personal communication 1979, Gordon Farabee, Mo. Dept. Conserv., Palmyra, Missouri). In the unchannelized Missouri River in South Dakota the 1972-1973 sturgeon catch consisted of 43 individuals,

or 3% of all species combined (calculated from Gould and Schmulbach 1973). In the same study, the reported harvest from the channelized Missouri River was three sturgeon. The Yellowstone River in Montana has a spring spawning run which provides an excellent fishery for anglers. Fishermen harvested about five sturgeon/km, a 1.1% exploitation rate for 1974 through 1976 (calculated from Elser et al. 1977). A spawning run in Wisconsin also provided five sturgeon/km, an annual exploitation rate of about 2% for 1968 through 1974 (calculated from Christenson 1975).

Status and Threats to Survival of the Shovelnose Sturgeon

Commercial fishery statistics suggest a decline in abundance of the shovelnose sturgeon over much of its range since the late 1800's. Some populations, such as occurred in the Rio Grande River, appear to have been extirpated. However, the remaining populations appear to have stabilized at lower levels than previously existed, and the shovelnose sturgeon is common over much of its former range in the Mississippi Valley. Barring further changes in habitat and rate of exploitation, the shovelnose sturgeon should persist at present population levels.

RECOMMENDATIONS

1. The lake sturgeon no longer exists as self-sustaining populations in Missouri, and the fish that are occasionally caught here are probably recruits from reproducing populations in northern states. The loss of spawning areas may be the most important factor in preventing the reestablishment of self-sustaining lake sturgeon populations in Missouri. Opportunities for restoration of spawning areas seem limited. Because the lake sturgeon is a wide-ranging species, restoration efforts

should involve all the states within the species range.

2. The release of hatchery-reared fingerlings may offer a promising management tool for restoring lake sturgeon populations. The potential of this management tool should be explored.
3. Fishermen reports of lake sturgeon sightings could be helpful in monitoring efforts to reestablish lake sturgeon populations, so the support and cooperation of fishermen should be enlisted through personal contacts, news releases, and popular articles.
4. The rarity of pallid sturgeon in our collections provides support for the continued listing of this species as endangered in Missouri. Limited evidence suggests that populations of the pallid sturgeon may be declining throughout the species range. Studies are needed to determine whether the pallid sturgeon is endangered elsewhere in its range.
5. Hybridization with the shovelnose sturgeon may present a threat to survival of the pallid sturgeon. Studies are needed to determine if hybridization is occurring throughout the range of the species, or only within the area of the present study. Studies are also needed to determine if the hybrids are fertile, and to determine the extent of backcrossing of hybrids with the parent species. The factors bringing about hybridization should be determined as a basis for developing management strategies to minimize hybridization.
6. Trends in abundance of the shovelnose sturgeon could provide a useful indication of long-term changes in big-river habitat and fish communities. Therefore, we recommend continued studies on the shovelnose sturgeon to monitor its relationship with the pallid sturgeon and with the big-river fish community as a whole.

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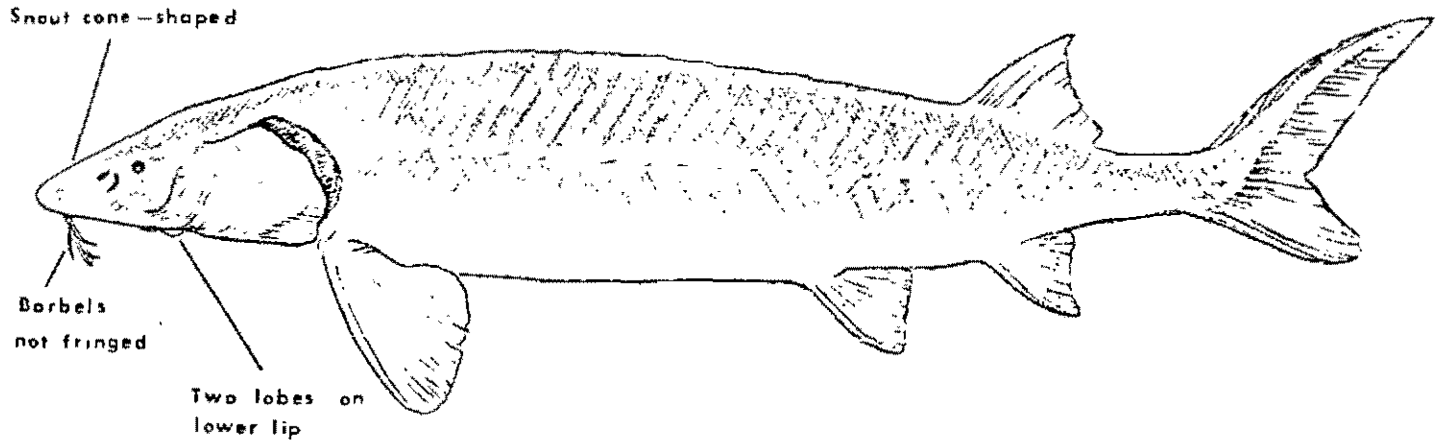
Appendix 1. Identification Leaflet.

MISSOURI'S STURGEONS

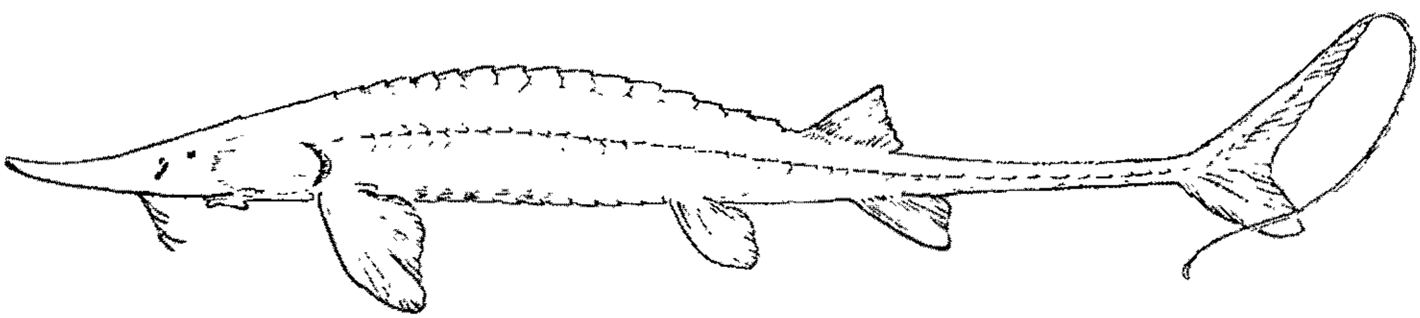
ILLUSTRATIONS BY REBECCA HAEFNER

The sturgeons are primitive fishes which once provided a valuable commercial fishery. One of the sturgeons, the shovelnose sturgeon, is still common in our big rivers, but the other two species are rare and considered *endangered*. These two species, the *lake sturgeon* and *pallid sturgeon*, are protected by rule 4.111 of Missouri Wildlife Code and must be returned to the water unharmed if captured. Biologists are studying these fish and they are particularly interested in any information you have on them. This leaflet is intended to assist fishermen in distinguishing between the shovelnose sturgeon, which is a catchable fish, and the two endangered sturgeons, which are protected.

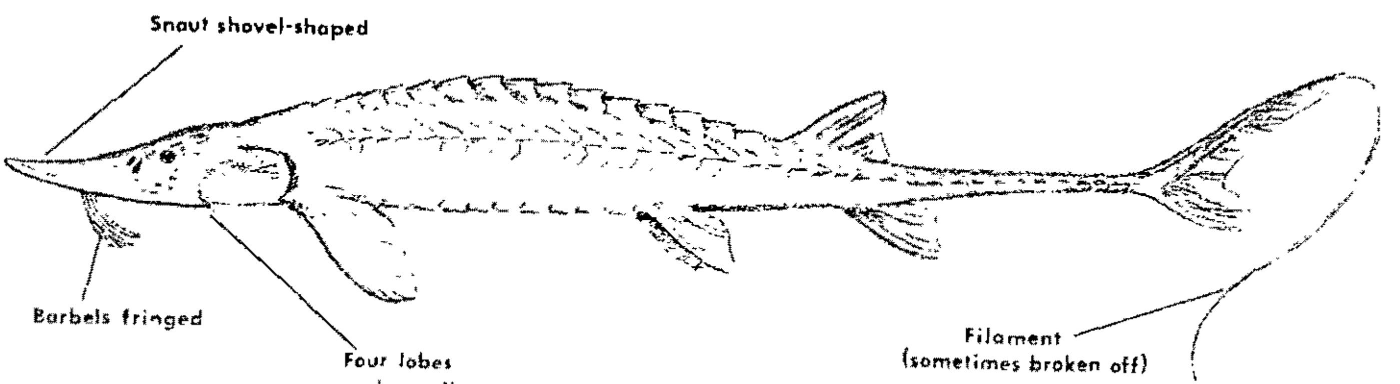


LAKE STURGEON

Lake Sturgeon (also known as rubbernose sturgeon or dogface sturgeon) — This sturgeon is the largest of the three species. Most lake sturgeons caught in Missouri weigh 30 pounds or more. This species is found in the Missouri and Mississippi rivers, but is rare. Identifying characteristics are its cone-shaped snout, only 2 lobes on the lower lip, and the barbels not fringed. It lacks the long slender filament on the tail fin which may be found in the other two species.



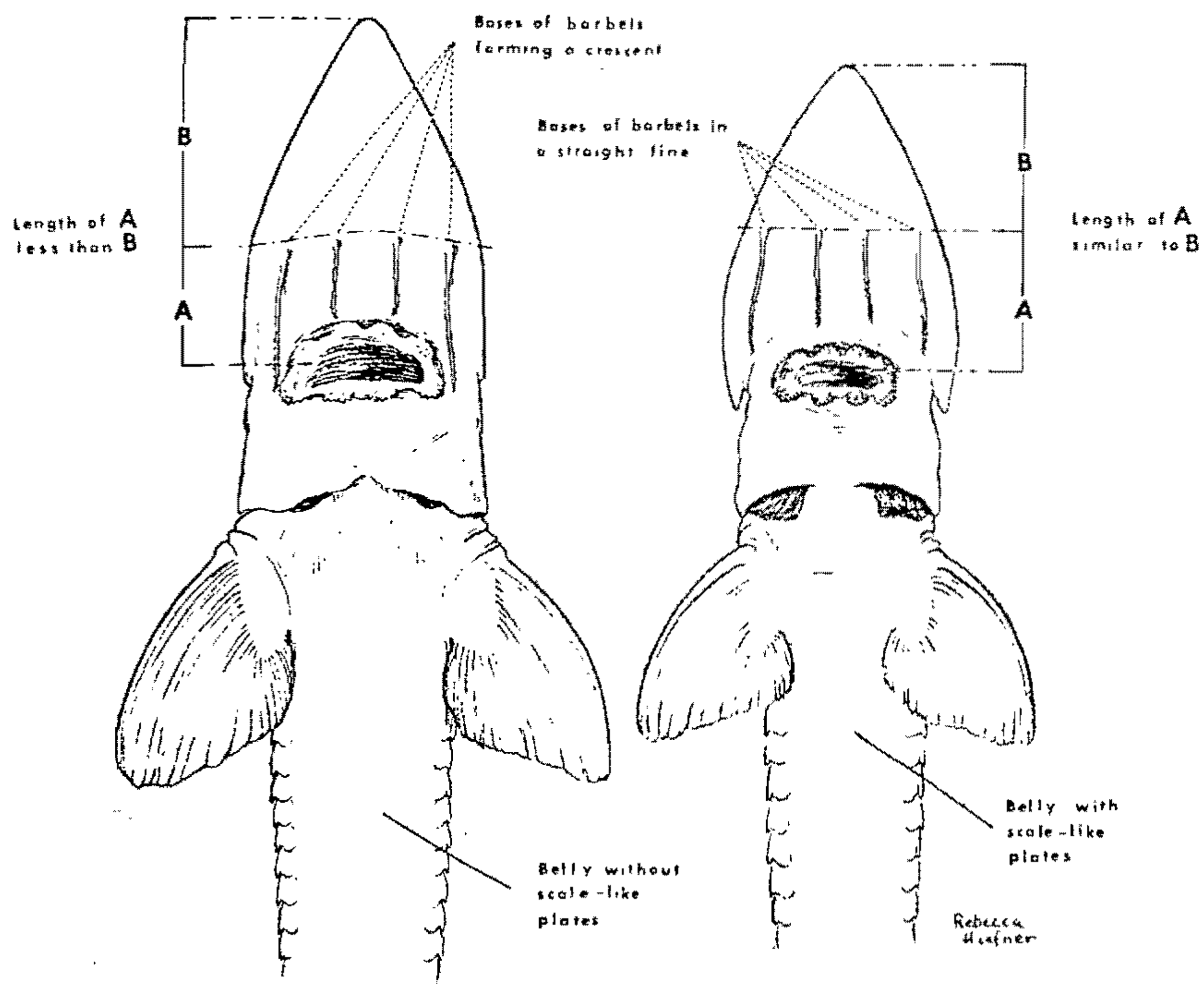
PALLID STURGEON



SHOVELNOSE STURGEON

The two species of river sturgeons (pallid sturgeon and shovelnose sturgeon) are similar in appearance. River sturgeons can be separated from the lake sturgeon by the shovel-nose snout, 4 lobes on the lower lip, and the fringed barbels. River sturgeons often have a long, slender filament on the tail fin, but this filament may be broken off in some individuals.

Characteristics for separating the two species of river sturgeon are illustrated below.



Pallid Sturgeon **Shovelnose Sturgeon**

Pallid Sturgeon (also known as white sturgeon, white shovelnose, or white hackleback) — This sturgeon has been found in the Missouri River and in the Mississippi from the mouth of the Illinois River downstream. It is very rare. The pallid sturgeon occasionally reaches 10 pounds or more, but on the average is much smaller than the lake sturgeon. Although this species looks much like the shovelnose sturgeon, there are three main characteristics that can be used to tell them apart. The pallid sturgeon has a skin-like scaleless belly, a longer flatter snout with the barbels attached closer to the mouth than the tip of snout, and has the bases of the inner barbels set somewhat ahead of the bases of the outer barbels. Its color is usually grayish-white.

Shovelnose Sturgeon (also known as brown sturgeon, hackleback, switchtail, and sand sturgeon) — Found throughout the Missouri and Mississippi rivers, this is our most common sturgeon. More than 90% of the sturgeons caught are shovelnose. It is also the smallest of our sturgeons, rarely exceeding 3 feet in length or 5 pounds. Unlike the pallid sturgeon, it has the barbels attached midway between the mouth and tip of snout, the bases of the inner barbels set in line with or ahead of the bases of the outer barbels, and has thin scale-like plates on the belly. The shovelnose sturgeon's color is usually reddish-brown or buff.

Fishermen are encouraged to report sightings of the lake sturgeon and pallid sturgeon, so that more can be learned of their status. Also, we are studying the habits of the shovelnose sturgeon with tag recovery methods. If you catch any turgeons with tags, either yellow plastic ones in the dorsal fin or metal bands around the pectoral fin, please send the tag along with the river location and date to:

Doug Carlson
Missouri Department of Conservation
1110 College Avenue
Columbia, Missouri 65201

Appendix 2. Letter to Fishermen.

March 14, 1978

Dear Fisherman:

We are doing a study of sturgeons in the Missouri and Mississippi river. These fish are important because they support a fishery and are valuable indicators of quality of big river habitat. I want to find out where these sturgeon live, how far they move, how old they get, and where they lay their eggs. What you know would help in this study. I want you to fill out this card. If you have more information on sturgeon, we want to come talk to you or call you.

Missouri has three kinds of sturgeons (see attached sheet). Two of these (lake sturgeon and pallid sturgeon) are less abundant than they used to be and the Missouri Department of Conservation has felt it necessary to protect them. I am interested in knowing of recent catches or sightings of these two sturgeons. The third kind (shovelnose or hackleback sturgeon) is still common is some areas. We are studying the shovelnose sturgeon to learn how valuable they are to the fishermen, if we are losing them in some areas, and where they come from. This will help us know what is causing their decline and tell us what we might do to make it better for them. We can learn this if you tell us where and when you catch sturgeon which have tags in them. The tags are metal bands around the front fin or yellow tubes in the top fin. The success of the study depends upon your help in returning these tags, and it would be greatly appreciated. Please send them to:

Doug Carlson — Phone - office - 314-449-3761
Missouri Department of Conservation — home - 314-445-1108
1110 College Avenue
Columbia, Missouri 65201

Also, please take the time to fill out and mail this postcard. It will help us a lot.

Thank you,

Doug Carlson

Doug Carlson
Fisheries Biologist

DC:mf
Enclosure

Appendix 4. (cont.)

	Shovelnose			Pallid	Hybrid
	Mo. R.	Upper Miss. R.	Middle lower Miss. R.	All stations	All stations
Trichoptera	16	13	16		
Phryganea	2				
Cheumatopsyche	14	22			
Potomyia flava	42	38	22	2	3
Hydropsyche orris	42	47	30	2	5
H. frisoni		2		2	
H. simulans	53	17	8	1	1
Neureclipsis	21	3	2	1	1
Ceraclea	2				
Lepidostomidae	4	1			
Trichoptera parts	27	16	3	5	1
Lepidoptera	23	3			
Coleoptera	20	6	4		
Scarabaeidae	11				1
Elaterid	16	1	2		
Staphylinidae	1				
Curculionidae		1			
Lampyridae	1				
Coccinellidae			1		
Heteroceridae	1				
Gerridae		1			
Dryopidae	4		1		
Hydrophylidae	7		1		
Berosus	2	1			
Dytiscus	8	1			
Rhantus		1			
Sterelmis sp.	2	7			
Coleoptera larvae	31	4	1	1	1
Diptera	2	1			
Protoplasa	1				
Chaoborus	7	1			
Chironomidae	77	78	17	4	5
Ceratapogonidae (*Bezzia*, *Probezzia*)	67	41	29	3	3
Culicoides (*Stilobezzia*)	8	2	7		
Dolichopodidae	3				
Tipulidae (*Dicranota*)	19	1	1	1	
Tipula	6				
Erioptera	10				
Simuliidae	11	1			
Empididae	1				
Stratiomyidae	3				
Psychodidae	3		2		
Ephydridae	1				
Eristalis	8				
Sciomyzidae	1				

Appendix 4. (cont.)

	Shovelnose			Pallid	Hybrid
	Mo. R.	Upper Miss. R.	Middle lower Miss. R.	All stations	All stations
Tabanidae	5	3			
Chrysops	26				
Muscoidea	46	3	1	1	
Muscidae	9	1			
Brachycera pupa	2				
Adult parts	8	3			1
Terrestrial insects	3	1			
Orthoptera	5	2	4		
Tetrigidae	8				
Tridactyliidae	2	1		1	
Aphid	3				
Cicada	8				
Mecoptera	1				
Hymenoptera	36	12	8	3	2
Crustacea					
Isopod	2				
Lirceus			2		
Asellus	8	6	2		
Amphipod (Hylella)	6	2			
Gammarus	1	2	2		
Crayfish	2	4	5		2
Copepoda	2	11			
Cladocera	4	2	1		
Ostracoda	2				
Pelecyopoda (Spaeridae)	3		2	1	1
Gastropoda		2			
Acari		1			
Centipede		2			
Spider	14	7	1	1	
Nematoda	21	21	11	4	1
Nematamorpha (Gordiida)					
Oligachaeta	12	3			
Hirudinea	2	2			
Tremetode (parasite)			1		
Vertebrate (Fish, cyprinid & *Hybopsis*)	2	1		5	3
Fish scales		7	1		
Fish eggs	3	2			
Plant seeds	31	13	5	2	
Material (duckweed)	74	54	22	7	5
blastocyst		1			
Sand	35	45	20	2	2
Unidentified insect	12	14	2		
Digested matter	112	108	41	9	5
Synthetic fiber	1	2			1
Aluminum foil					1
String	1				
No. fish examined	116	115	40	9	6

Appendix 3. Postcard Survey.

BUSINESS REPLY MAIL

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

POSTAGE WILL BE PAID BY

Fish and Wildlife Research Center
1110 College Avenue
Columbia, Missouri 65201

FIRST CLASS
PERMIT NO
89
JEFFERSON CITY, MO

MISSOURI DEPARTMENT OF CONSERVATION
Sturgeon Survey

1) Have you ever caught sturgeons? __________ (If no, go to question 5) What time of year did you catch them? __________

2) Have you ever run on to large numbers of sturgeons? When (mo., yr.) __________
Where (be as specific as possible, giving river mile if known) __________

3) Are they a valuable fish to you, or what do you do with them? __________

4) Have you ever caught or seen the lake sturgeon or pallid sturgeon? __________
When (mo., yr.) __________ Where __________

5) If you have any more information about sturgeons, please put your phone number here so that I can call or visit __________

6) Additional comments:

Thank you.

BUSINESS REPLY MAIL

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

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Fish and Wildlife Research Center
1110 College Avenue
Columbia, Missouri 65201

FIRST CLASS
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2) Have you ever run on to large numbers of sturgeons? When (mo., yr.) __________
Where (be as specific as possible, giving river mile if known) __________

3) Are they a valuable fish to you, or what do you do with them? __________

4) Have you ever caught or seen the lake sturgeon or pallid sturgeon? __________
When (mo., yr.) __________ Where __________

5) If you have any more information about sturgeons, please put your phone number here so that I can call or visit. __________

6) Additional comments:

Thank you.

Appendix 4. Number of sturgeon stomachs containing each food item.

	Shovelnose			Pallid	Hybrid
	Mo. R.	Upper Miss. R.	Middle lower Miss. R.	All stations	All stations
Arthropoda					
Insecta					
Plecoptera	1				1
Taeniopterayx	1		12		
Acroneuria	1				
Neoperla	2				
Perlesta	2	2			
Isoperla	28	13			2
Ephemeroptera	4				1
Tortopus				1	
Pentagenia	15	14	7	1	2
Hexagenia	14	23	17	3	2
Eporon		3			
Potomanthus		2			
Siphlournidae		2		2	1
Isonychia	9	8	1		
Baetis sp.	3	2			
Tricorythodes	2		1		
Caenis sp.	1	3		1	1
Pseudiron	15	7	5	1	
Heptagenia	18	7	8	2	1
Stenonema	4	6	1		
Stenacron	1	3			
Odonata	3				
Zygoptera	3	1			
Coenagrionidae		1	1		
Enellagma	1				
Argia	13	4		1	2
Hetaerina	1				
Calopteryx	1				
Ischnura	1	1			
Ansioptera	1			1	
Libellulidae	13				
Progomphus	6	1	1		1
Gomphus (*G. vastus*)	2				
Gomphus (*G. crassus*)	6	1	3	1	
Hemiptera	5				
Corixidae	19	4		1	
Cicadellidae	3	7	5	2	
Heteroptera	1	3	2		
Megaloptera					
Corydalus	2				
Chauloides	1				
Sialis	3				

Table 1. Numbers of shovelnose, pallid, and hybrid sturgeons obtained at [illegible] stations on the Missouri and Mississippi rivers.

Station	Shovelnose sturgeon	Pallid sturgeon	Hybrid sturgeon	Total
Missouri River				
Brownsville	446	2		448
St. Joseph	65	1		66
Kansas City	355	1	3	359
Waverly	83			83
Brunswick	111			111
Easley	443	1		444
St. Louis	146		2	148
Mississippi River				
Canton	45			45
Saverton	325			325
Chain of Rocks	1,675		9	1,684
Ste. Genevieve	97	1		98
Cairo	181	5	1	187
Caruthersville	64			64
Totals	4,036	11	15	4,062

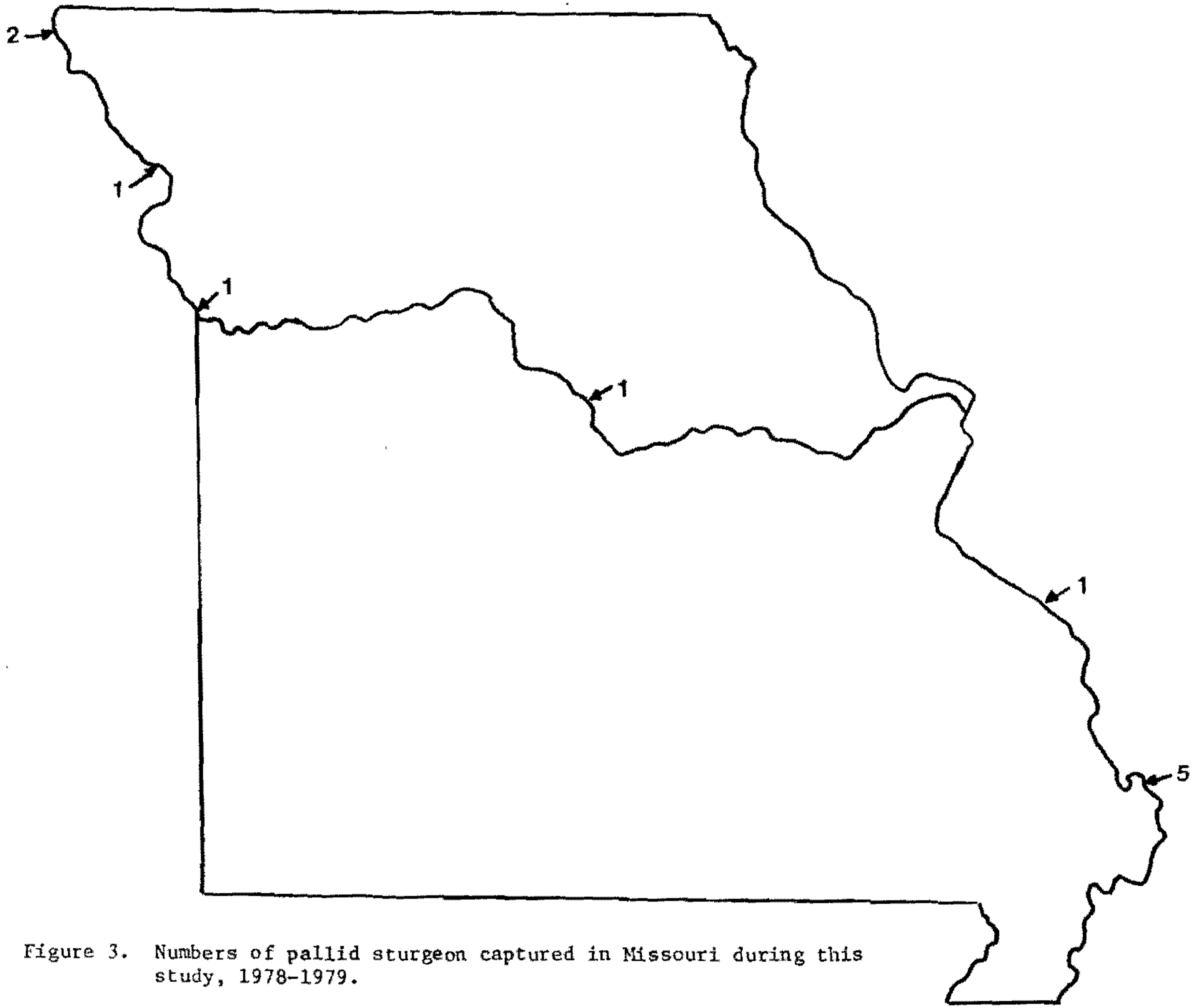

Figure 3. Numbers of pallid sturgeon captured in Missouri during this study, 1978-1979.